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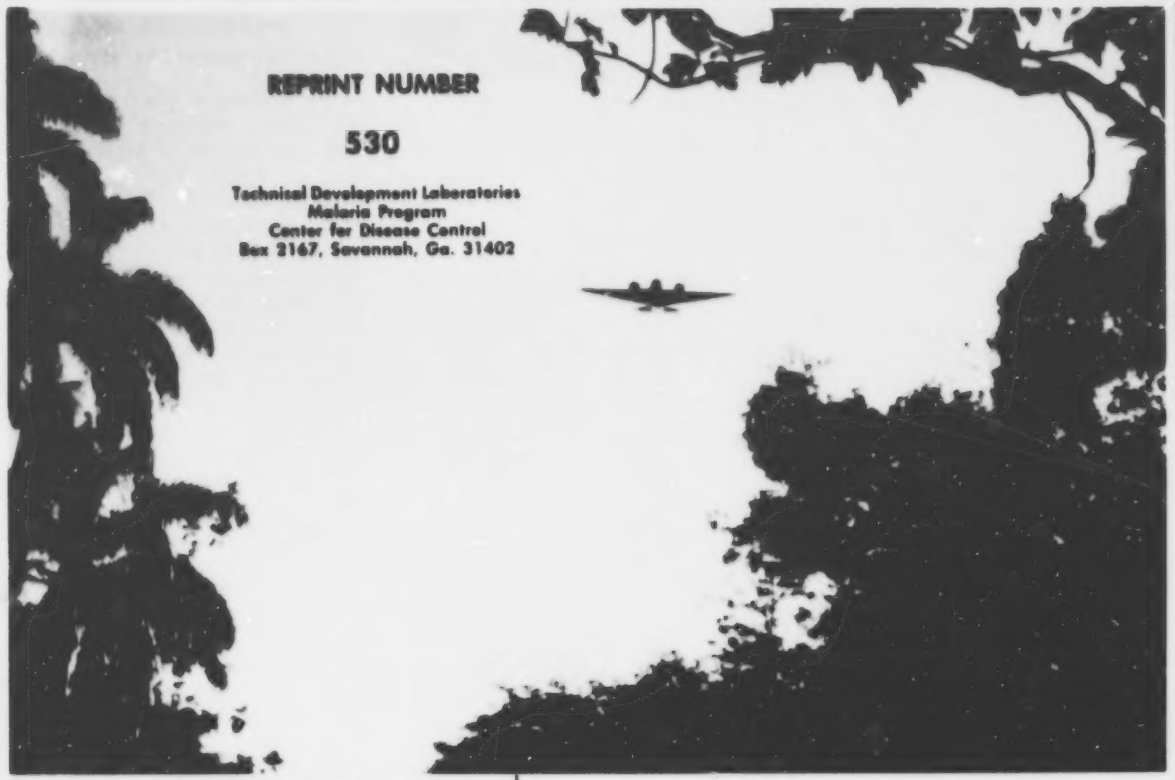

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Technical Development Laboratories
Malaria Program
Center for Disease Control
Box 2167, Savannah, Ga. 31402

This Technical Development Laboratories aircraft is spraying ULV malathion in Haiti. Below: sampling for **Anopheles albimanus** larvae in the Haiti ULV study area. Below left: Cross section of the study area. Below right: Mist net being erected to sample birds for cholinesterase level determinations in the area.

PUBLIC HEALTH PESTICIDES

1973 Center for Disease Control Report on Public Health Pesticides for mosquitoes, flies, fleas, bedbugs, ticks, chiggers, lice, cockroaches, venomous arthropods, and rodents, from the Technical Development Laboratories, Malaria Program, Center for Disease Control, Public Health Service, Health Services and Mental Health Administration, U.S. Department of Health, Education, and Welfare, Savannah, Georgia 31402.

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PUBLIC HEALTH PESTICIDES

PUBLIC HEALTH Pesticides is the annual release of the Center for Disease Control (CDC) that presents updated information on pesticides used in the control of arthropods and rodents of public health significance. The data reported are from the literature and from unpublished findings of CDC and other research organizations[1]. Unpublished information from CDC is designated by the Letters CDC, those from other sources by the superscript given in footnote 1.

The purpose of the article is to keep health departments, municipalities and other agencies involved in the control of disease vectors and rodents currently advised on compounds that are effective and can be used safely. Emphasis is placed on new developments in the general field of vector control and on compounds of value to agencies engaged in control or eradication programs. When no marked changes have occurred in the data from the previous year, the information may be presented unchanged from that in the preceding year's release. The sequence of listing of the toxicants in the text or in the tables is alphabetical where feasible and in no way implies any priority in the selection of a compound. **The decision to apply any compound is the responsibility of the agency or individual concerned. The comments on the various pesticides refer to experimental or reported results and do not represent a specific recommendation or endorsement of the pesticide of of the application equipment involved. Each person applying a pesticide should be certain that the intended use is in conformance with existing federal, state and local regulations. In addition, since the pesticide application procedures mentioned are only outlined or described briefly, anyone unfamiliar or inexperienced with a specific procedure must seek the advice of a person experienced in its use or obtain the necessary training from a recognized source.** The latter is even more critical now in view of the amended legislature on pesticides as described on page 19.

Under the specific categories listed for arthropod control, the compounds included are commercially available. However, there are numerous compounds, not yet commercially available, that have been tested against arthropods of public health importance. Information on such pesticides can be obtained by writing to the Technical Development Laboratories, Center for Disease Control, P.O. Box 2167, Savannah, Georgia 31402. *Inquiries should specify the compound and insect involved.*

In the text of the resume, the chemical is designated by its accepted common name which is indicated by lower case (*e.g.*, fenthion). If such a designation is not available, the capitalized trade name or code name is listed[2]. When a common name first becomes available for a compound, it replaces the trade name or code name but the latter also is included in parentheses. Because certain pesticides are marketed under a variety of trade names, it is not feasible to quote all such names nor is it permissible to select one of several trade names since to do so could be interpreted as indicating Federal endorsement of the product[2]. To assist the reader in identifying specific compounds, several references on toxicants and their synonyms are given in footnote 3.

[1]Special acknowledgment is made to the organizations listed below for their cooperation in furnishing unpublished experimental data for inclusion in the resume. References to these organizations are shown by the capital letter indicated: Insects Affecting Man Research Laboratory, U.S. Department of Agriculture[A]; the Bureau of Vector Control and Solid Waste Management, California Department of Public Health[B]; the West Florida Arthropod Research Laboratory, Florida State Board of Health[C]; the Environmental Biology Branch, Tennessee Valley Authority[D]; and the Metropolitan Mosquito Control District, St. Paul, Minnesota[E].

[2]Use of trade names is for identification purposes only and does not constitute endorsement by the Public Health Service or U.S. Department of Health, Education, and Welfare.

[3]Frear, Donald E. H. Pesticide Handbook-Entoma. 1971. 23rd Edition. College Science Publishers, State College, Pennsylvania, 253 pp; Kenaga, Eugene E. and William E. Allison. 1969. Commercial and experimental organic insecticides (1969 revision). Bull. Ent. Soc. Amer. *15*(2):85-148; and Billings, S. C. 1969. Additions and corrections — Consolidated list of approved common names of insecticides and certain other pesticides. Bull. Ent. Soc. Amer. *15*(4):380.

PESTICIDES AND ENVIRONMENTAL HEALTH

The prolonged litigation over the detrimental effects on the environment by the use of DDT for controlling insects was brought to a close on June 14, 1972, by a statement of William D. Ruckelshaus, Administrator, Environmental Protection Agency, to the effect that general use of DDT would be banned in the United States as of December 31, 1972. Evidence indicated that the major use of DDT was on cotton, peanuts, and soybeans. The only exceptions to the ban on general agricultural use referred to the limited application of DDT for weevil control on sweet potatoes and heavy infestations of corn borer in green peppers. Such exceptions were temporary pending further evidence of the lack of effective substitutes. In the control of public health insects DDT has not been used in most health programs for many years. Nonetheless, the EPA statement indicated that if the need should arise and health officials were of the opinion that DDT applications were required for control of a disease vector, the ban order would not prevent the use of DDT under such circumstances. One of the conclusions listed in the EPA statement was that "DDT when labeled with directions for use by and distribution to only U.S. Public Health Service officials or for distribution by or on approval by the U.S. Public Health Service to other health service officials for control of vector diseases, for use by and distribution to the Public Health Service, USDA, and military for quarantine use; for use in prescription drugs to be dispensed only on authorization by a certified medical doctor" along with the caution printed in bold type "use for any purpose not specified or not in accordance with directions and use by unauthorized persons is disapproved by the Federal Government: this substance is harmful to the environment," is not "misbranded."

The use of DDT for bat and mouse control was also banned by the EPA directive. However, prior to the December deadline, the application of DDT dusts was approved by EPA to control bat colonies in two counties in Delaware where fear of a rabies epidemic arose after several humans had been

attacked by bats and rabies was detected in captured specimens.

Other organochlorine compounds such as dieldrin, chlordane, and aldrin are currently under review by EPA and decision on their usage may be forthcoming in 1973.

Many of the states are considering or have adopted legislation restricting or regulating pesticides. BECAUSE OF THE CHANGES AND AMENDMENTS THAT MAY OCCUR IN THE REGULATORY ASPECTS OF PESTICIDES AT STATE AND FEDERAL LEVELS, ANY PERSON USING PESTICIDES SHOULD CONSULT AN APPROPRIATE AUTHORITY OF THE STATE REGULATORY AGENCY BEFORE APPLYING A PESTICIDE WHOSE USE STATUS IS IN QUESTION. *Information in this release on pesticide use reflects the status as of February 1, 1973.*

In this release, DDT will be mentioned for domestic use only when its specified use does not conflict with the EPA directive. However, the user should contact the state agencies for agriculture, health and game management to be certain that there are no local restrictions on its application.

The ban order on DDT in the United States in no way affects its export to other countries for use against agricultural or public health pests. However, certain foreign countries, such as Sweden, Italy and Canada, have banned the use of DDT, although it may still be applied for specific purposes. Internationally, DDT plays a major role in controlling public health diseases. The World Health Organization considers that the concept of malaria eradication rests completely on the continued use of DDT. In such programs, DDT is the principal insecticide used in the residual treatment of dwellings. When so used, its application minimizes possible contamination of the environment as compared to situations where it is used out-of-doors as a general area treatment. DDT also has a definite value overseas in the control of trypanosomiasis, onchocerciasis, louse-borne typhus and bubonic plague.

Most alternate pesticides for DDT represent a material increase in cost, a factor considered of less consequence in the United States than in the developing overseas areas. In the United States the three elements, vector control, protection of nontarget organisms and contamination of the environment, must be considered *value for value*. With this viewpoint, the added cost of insecticides that are potentially less harmful to nontarget organisms is compensated for by the protection of the wildlife and the decrease in environmental contamination.

A second major development in the pesticide situation was the passage of Public Law 92-516 by the 92nd Congress on October 21, 1972. Known as the Federal Environmental Pesticide Control Act of 1972, it amended the present Federal Insecticide, Fungicide and Rodenticide Act. The new Act specifies that pesticides shall be classified for general use, restricted use or both. General use pesticides are those which when applied in accordance with its directions for use, warning and cautions or for one or more of such uses for which it is registered or in accordance with a widespread and commonly recognized practice will not generally cause unreasonable adverse effects on the environment. Restricted use pesticides[4] are those that when as outlined in the previous sentence may generally cause without additional regulatory restrictions unreasonable adverse effects on the environment including injury to the applicator. Unreasonable adverse effects is defined as any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide.

Pesticides classified for restricted use because of hazard to the applicator or other persons or because of hazard to the environment shall be applied only by or under the direction of a certified applicator. The standards for Federal certification of pesticide applicators are to be established by EPA. To be certified, an individual will have to establish that he is competent in the use and handling of pesticides.

The regulations for registering and classifying pesticides under the new Act must be set forth within 2 years after October 21, 1972. Any requirement that a pesticide be registered for use only by a certified applicator will not become effective until October 21, 1976. The same 4-year period also applies to the certification of applicators. Standards for Federal Certification of applicators are to be provided by EPA by October 21, 1973.

[4]May be limited to a particular use, not necessarily all uses.

CONTROL PRINCIPLES

The major purpose of this release is to discuss the pesticides that are of value in control of arthropods and rodents. It does not attempt to provide the information needed to conduct an organized mosquito or vector control program. However, operational principles that are the foundation of successful control programs warrant consideration.

Pesticides per se constitute only one facet of vector control. Their relative value varies with the vector and local conditions. During emergency or vector borne disease situations chemical measures occupy a dominant role because of the need for a rapid means of suppressing the vector population, nonchemical measures because of their slowness of effect are not feasible under these circumstances.

Effective vector or rodent control depends upon a competent program director who has the technical knowledge and managerial skills to utilize all the suppressive weapons available. He must recognize the fact that prevention of arthropod or rodent production is the basic method for achieving successful control. Likewise, his entire approach will be hampered unless he succeeds in getting the community environmental groups and the individual to understand the objectives of the program and the types and safety of the control measures used. An informed public is a vital asset to his efforts.

Much attention today is focused on the integrated control approach and on pest management practices. Although both of these aspects have been followed to a varying extent in the past, it is obvious that the current concern about the environment requires a much broader consideration of the possible effect of measures designed to suppress an arthropod pest. At the same time it is equally important that other elements of man's activities (*e.g.*, housing developments, road construction, river dredging) be assessed from the viewpoint of their impact on creating new or greater

problems of vector production. Overall consideration of the various elements that have a relationship to vector control activities are now far more numerous and involved than heretofore. Hence, persons directing such programs must thoroughly appraise the different facets of their operations and insure that they are accomplishing their objectives without adversely affecting man or his environment. Greater emphasis on arthropod surveillance is required to define the population trends and sources of the species involved. Only when such information is continuously supplied to the supervisor will he know which control measure to apply and where, when and how often treatment is required. This approach is mandatory not only from the viewpoint of economy but also from that of keeping to a minimum the amount of chemical control necessary to obtain effective vector control.

In choosing a pesticide, the operator seeks a toxicant that is highly effective against the pest and yet, when used as directed, is not harmful to humans and other elements of the environment. Because each control situation differs, the relative emphasis placed on certain characteristics of the pesticide (*i.e.*, odor, cost, toxicity, persistence) may vary considerably. In most instances the decision reached will be a compromise to serve the interests of the groups involved. For example, where the use of an inexpensive but highly toxic organophosphorus (OP) insecticide may be detrimental to wildlife, the substitution of a more costly compound of lesser harm to nontarget organisms may be necessary. *The advice and suggestions of other agencies with interests in the total environment should be sought so that the control program is considerate of the concern of the other groups and is amenable to their interests.*

Vector control operations thus involve surveillance, education, source reduction, and pesticides. The latter is supplemental in community programs, particularly to source reduction procedures such as drainage, filling or flooding to eliminate mosquito breeding sites or the proper storage collection and disposal of human and animal wastes to curb fly production.

Since the composite picture of vector control has broadened greatly in recent years and restrictions on pesticide use have increased, the proper training of the individuals involved is of critical importance. Courses for such training for sanitarians, mosquito abatement workers, and others are offered by the Laboratory Division, Center for Disease Control, Atlanta, Ga. 30333.

RESISTANCE

Resistance to certain chemicals has occurred in a number of species. A recent review reported that whereas in 1958 thirty-five species were resistant to the organochlorine compounds and four were also resistant to the OP insecticides; in 1971 there were 104 resistant species, 18 of which had developed resistance to OP materials.

In the control of many species of mosquitoes and of house flies, the organochlorine compounds are no longer of value and in some species the same applies to a number of OP insecticides. In the United States this is particularly true of the *Musca domestica*. In California, *Culex tarsalis* in several counties is no longer controllable by OP larvicides. *Aedes nigromaculis* also is highly resistant to the available OP larvicides in various parts of the same state and in some localities is not susceptible to carbamates. Despite such discouraging developments, some species continue to succumb to the same pesticides even though the identical control measures have been in effect for many years. Although industrial know-how continues to synthesize new compounds, their usefulness remains unproven until tests demonstrate that cross resistance is not present. As a general rule such measurement of cross resistance should extend to several localities before a premature conclusion on the lack of usefulness of a new compound is known.

One of the principal problems in the use of new insecticides in public health is the fact that such compounds may have been used extensively in agriculture prior to their consideration in the control of a public health vector. As a result, the initial change of a susceptible field population of a vector species towards a resistant one may be stimulated by the application of pesticides in agriculture. Consequently, when the compound is first used in public health there may already be a slight or high resistance to it in the vector population. Such may be true whether it is the same compound used in agriculture or is a related one. Thus, an evaluation of the resistance levels of the species to new public health pesticides is extremely essential in any area where insecticides have been used for purposes other than vector control.

Before assuming resistance is the cause of poor control the supervisor must be certain that poor control is not due to other factors such as careless spray techniques, lack of knowledge about insect habits, or faulty source reduction procedures. Resistance detection methods suitable for field use are now available for more than 15 species of insects as well as for rodents[1]. With these techniques undue emphasis should not be given to slight changes in the insects' response to the toxicant. *Any decrease in susceptibility should be substantiated by the observation of a loss of field efficacy of the chemical treatment before the operator seeks another toxicant or considers a change of procedure.*

PESTICIDE HAZARD

Pesticides must always be handled in such a way that the possibility of harm to nontarget organisms (including man), either through contamination of food and water or by contact, is kept to a minimum. All spraymen should be given intensive training in the proper handling of pesticides. Accidents are few when the individual knows and follows the proper procedures. Eight basic rules to minimize hazard are:

(a) Know the material being applied; *READ THE CONTAINER LABEL AND UNDERSTAND THE DIRECTIONS* for preparing and applying the pesticide, and then *FOLLOW THE DIRECTIONS.*

(b) Wear protective clothing and headgear, and avoid prolonged exposure to pesticides. Special care should be exercised to prevent inhalation and contamination of the skin when handling insecticidal concentrates (i.e., use respirators, impermeable aprons and gloves).

(c) Avoid contamination of foods

[1]These techniques are described in the World Health Organization Technical Report Series No. 443, Insecticide Resistance and Vector Control, Geneva, 1970.

or drinking water of man and animals.

(d) When pesticide contamination of the body occurs, wash the affected area quickly and thoroughly with soap and water. Wash with soap routinely after each day of spraying.

(e) Keep spray equipment clean and in good condition. Flush insecticidal equipment only where contamination will not affect man or wildlife.

(f) *STORE PESTICIDES IN PROPERLY LABELED CONTAINERS OUT OF REACH OF CHILDREN AND ANIMALS.*

(g) Dispose of empty containers safely (*e.g.*, bury them under at least 2 feet of soil).

(h) *KNOW THE EMERGENCY MEASURES FOR TREATING ACCIDENTAL POISONING*[6].

Guides to the toxic hazard of pesticides to mammals and other animals are available from the various pesticide manufacturers and from the EPA, 4770 Buford Highway, Chamblee, Georgia 30341. These guides contain data obtained from toxicological studies conducted on rabbits, rats and other test animals (Table 1). Data on the toxicity of pesticides to wildlife are available from publications by the Department of Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife[7]. Such data are extremely valuable in comparing the relative toxicities of the different compounds. However, the *KEY TO THE SAFETY OF HUMANS AND OTHER NONTARGET ORGANISMS IS A KNOWLEDGE OF THE HAZARDS INVOLVED IN HANDLING AND APPLYING PESTICIDES.* To assess these hazards, consideration must be given to the chemical properties of the toxicant formulation (absorption characteristics, stability, etc.), use concentration, site of application, amount of area involved, frequency of treatments and exposure time. For example, the application of an insecticide as a spot treatment inside homes offers little or no hazard to wildlife in comparison to aerial applications of a pesticide to an aquatic situation such as a marsh or lake. Likewise, repeated applications of a pesticide may pose a hazard not present when only a single or a few treatments are required. Full consideration must always be given to the fact that different species of animals may vary widely in their sensitivity to injury from a pesticide. Even among closely related animals there may be a marked variation in response.

Table 1. Acute oral and dermal LD_{50} toxicity values of selected pesticides to female rats (mg./kg.).[a]

Chemical Class	Pesticide	Oral	Dermal
Organochlorine:	chlordane	430	690
	DDT	118	2,510
	dieldrin	46	60
	lindane	91	900
	methoxychlor	6,000[b]	>6,000
Organophosphorus:	Abate	13,000	>4,000
	chlorpyrifos	82	202[b]
	diazinon	285	455
	dichlorvos	56	75
	dimethoate	245	610
	fenthion	245	330
	Gardona	1,125	>4,000
	malathion	1,000	>4,444
	naled	250[c]	800[c]
	parathion, ethyl	3.6	6.8
	parathion, methyl	24	67
Carbamate:	propoxur	86	>2,400
	carbaryl	500	>4,000
Arsenical:	paris green	100	2,400
Botanical:	pyrethrum	263[d]	—
	resmethrin	4,230[d]	—
Miscellaneous:	diphacinone	1.9[c]	—
	pindone	280[c]	—
	warfarin	3[c]	—

[a] All figures taken from tests performed by the Chamblee Toxicology Laboratory, Environmental Protection Agency, 4770 Buford Highway, Chamblee, Georgia 30341.
[b] Sex not specified.
[c] Data for male specimens.
[d] Unpublished data.

A summary of the evidence concerning the impact of pesticides on nontarget organisms was issued in 1971[8]. This resume covers the effect of insecticides, herbicides, and fungicides on mammals, fish, birds, arthropods, plants, and other nontarget organisms as well as information on the environmental problems resulting from pesticide residues.

ALTERNATIVE METHODS OF PEST CONTROL

During the past 7 years much more attention has been devoted to developing and evaluating methods that would decrease or replace the use of insecticides for the control of agricultural and public health pests. These recent efforts have been directed at genetic control techniques, biological control agents, and hormones. In agriculture, successful application of the genetic control method of releasing sterilized males has been made against the screwworm fly in southeastern United States, the melon fly on the island of Rota, and the oriental fly on Guam; eradication of the species being achieved in these areas. Against public health pests, primarily mosquitoes, these methods have not met with the same degree of achievement. However, in experiments with isolated populations of *Culex*, promising results have been obtained with the release of chemosterilized males in studies on an

[6] Information on this subject is included in the Clinical Handbook on Economic Poisons, which is available as Public Health Service Publication No. 476 from the Superintendent of Documents, Washington, D.C. 20402. Price, 55 cents.

[7] Information on this topic is available in the Handbook of Toxicity of Pesticides to Wildlife, Resource Publication No. 84, March 1970, which is available from the Superintendent of Documents, Washington, D.C. 20402. Price, $1.00

[8] Ecological Effects of Pesticides on Nontarget Species, Executive Office of the President, Office of Science and Technology, available from the Superintendent of Documents, Washington, D.C. 20402. Price, $2.00

island near Florida and with cytoplasmic incompatible males in a village in Burma. Recent studies in El Salvador by the USDA[A] and CDC's Central America Malaria Research Station (CAMRS) have been successful in greatly reducing populations of *Anopheles albimanus* in an isolated lake area. Studies of these two techniques of genetic control as well as with genetic translocation are now in progress in several parts of the world.

Biological control agents are also under intensive study. Although more than 700 species of predators and 500 species of parasites attack arthropods of medical importance there is at present no agent available for use on an operational basis. Experimentally, two species show promise against mosquitoes. *Reesimermis nielsoni*, a nematode, has been shown by the USDA in Louisiana to be effective against mosquito larvae and a fungus, *Lagenidium culicidum*, was found by CDC to be lethal to a number of culicine species. An exploratory field test in California (CDC and B) demonstrated the fungus to be highly effective against *C. tarsalis*. The one biological control agent that has been and still is used in many areas to control mosquito larvae in restricted water sources is the top feeding minnow fish, *Gambusia affinis*. In subtropical areas the guppy, *Lebistes reticulatus*, also is of value as a culicine predator.

Research on the potential of hormones as a control agent has been stimulated during the past few years by the synthesis of various compounds that mimic the juvenile hormone in its effect on insect development. These developmental inhibitors show promise against the larvae of mosquitoes and house flies. Although chemicals, they differ from conventional pesticides in that they disrupt insect development rather than cause immediate death. Most inhibitors decompose rapidly in water which is beneficial to nontarget organisms but lessenstheir efficacy against the mosquito larval population. Fortunately, this problem appears susceptible to correction by formulation procedures. In addition, recently developed urea derived inhibitors are relatively stable in water.

Thus, at the present time, alternative methods to pesticide application in vector control remain at the experimental level. No agent as yet has been registered for use in controlling insects of public health importance. These alternative techniques (*e.g.*, bacteria, fungi, chemosterilants) will have to undergo the same careful scrutiny by regulatory agencies as is now true for conventional pesticides.

Because these alternative measures have not yet reached a stage of development to be of value in operational programs conventional pesticides will continue to play a significant role in the future in vector control programs. This fact places a greater emphasis on the necessity of discovering better methods of pesticide usage so as to minimize their hazard to man and his environment without sacrificing the benefits derived from these pesticides in protecting man from the disease and discomfort caused by these arthropods.

ARTHROPOD CONTROL

MOSQUITOES

Mosquitoes are the most important group of arthropods that transmit diseases to man. Mosquito-borne diseases include encephalitis, dengue hemorrhagic fever, filariasis, yellow fever and malaria. Numerous species are involved whose breeding habits, behavior and dispersal are markedly different. The eggs of certain species are capable of surviving for months on damp or even dry soil; other species require water for egg deposition, and the eggs hatch within a short period. Dispersal of species like *C. tarsalis* may extend for more than 5 miles whereas others, such as *Aedes aegypti*, possess a limited range of less than 0.5 mile. Consequently, control measures for mosquitoes, whether larvicides or adulticides must relate to the species or to a species group and cannot be considered as being applicable to mosquitoes in general.

The expanding picture of mosquito resistance to insecticides presents a major problem in the chemical control of mosquitoes, particularly in areas where extensive larviciding practices have been conducted (*e.g.*, California). In Florida larvae and adults from a field-collected strain of *Aedes taeniorhynchus* were shown to be 46 and 23 times, respectively, as resistant to malathion as a susceptible laboratory strain. The strain was susceptible to fenthion, propoxur, Abate, and naled. Resistance is found in anopheline vectors in many areas of the world, but the problem so far has been a major cause of failure of malaria eradication programs in only a few countries.

The pesticides employed in mosquito control are discussed under the method of application and their uses are summarized in Table 2.

The interior spraying of houses is rarely practiced in the United States but exterior spraying of shrubbery, hedges and under eaves is done in some areas of the country. In overseas areas interior house spraying is a standard procedure for malaria eradication programs. The insecticides, dosage and periods of efficacy are given in Table 2.

In outdoor panel tests (CDC) methoxychlor, a biodegradable organochlorine compound, has given 90% kills of dieldrin-resistant or malathion-resistant strains of *A. albimanus* for 9 weeks. However, in mud-lined experimental hut tests, the same dosage of methoxychlor was ineffective against free flying specimens of the malathion-resistant strain but persisted for 14 weeks against the dieldrin-resistant strain. The same compound failed to produce effective kills of DDT-resistant *Anopheles quadrimaculatus*.

Landrin, a carbamate, when applied at 200 mg./sq. ft. to experimental huts gave 90% or greater kills of free-flying *A. quadrimaculatus* for 12 weeks. This compound produces a fumigant effect similar to propoxur. Complete kills of adult mosquitoes not in contact with the residues were obtained for 13 weeks versus >20 for propoxur. The CAMRS evaluated Landrin in a village in El Salvador where two applications (June, October) were made at a target dosage of 200 mg./sq. ft. to 197 houses. Results indicated that Landrin was essentially equal in biological effectiveness to propoxur.

Outdoor treatments of compounds such as methoxychlor, malathion, fenthion, carbaryl, and naled are made for temporary control of adult mosquitoes around dwellings. The long lasting efficacy, characteristic of DDT formerly used for this purpose, usually is not obtained. Recent tests in Florida[C] indicate that the treatment of individual premises with 2%

malathion suspension at the rate of 16 lb. of toxicant/A. did not give satisfactory reduction of *Culex nigripalpus*.

Continuous vapor dispensers:

Formulation of dichlorvos in wax or resin allows the gradual release of the insecticidal vapor over an extended period. A concentration of dichlorvos in an enclosed space at or above 0.02 μg./liter of air will give complete mortality of adult mosquitoes. Thus, this type of treatment is effective against adult mosquitoes in homes, catch basins, cisterns and other types of confined areas. The amount of vapor produced by a dispenser is relatively uniform at a given temperature, but doubles for every 20° F. rise in the temperature range of 70° to 100° F. The number of dispensers required varies with the amount of ventilation in a room. Effective kills of caged mosquitoes for periods of 3 to 4 months have been obtained in tropical houses. In catch basins, one unit per basin has remained effective for periods of 11 to 18 weeks against *Culex pipiens quinquefasciatus*. In situations where there is a minimum of ventilation, as in homes in the temperate zone, one strip per 1,000 cubic feet of enclosed space is the maximum acceptable rate of treatment. *In the United States these dispensers should not be used where infants or aged persons are continually exposed to the vapor or in areas where food is prepared, served, or stored.*

In recent studies in Egypt a fluid type dispenser of dichlorvos was found to give effective kills of *Anopheles pharoensis* for approximately 5 weeks. One dispenser per 500 cu. ft. was required for the best results in the houses constructed of mud walls and thatch or wood roofs.

Space treatments:

Properly timed and applied, outdoor space treatments will temporarily reduce adult mosquito populations to low levels. Fog, dust, mist and ultra low volume (ULV)[9] applications have been shown to produce similar results against saltmarsh mosquitoes. For maximum operational efficiency, the performance characteristics of the equipment must be determined with each of the formulations employed. This assessment is of extreme importance with aerial or ground ULV applications in which undiluted con-

Table 2. Pesticides Currently Employed in Mosquito Control.[a]
(State or local regulations may impose certain restrictions on the use of these compounds; therefore, the individual should consult local or state authorities on the accepted use practices.)

Type Application			Toxicant[b]	Dosage	Remarks
				Mg./sq. ft.	
RESIDUAL SPRAY			malathion	100 or 200	For use in United States as an interior house treatment. — Particularly persistent on wood surfaces and remains effective for 3 to 5 months.
			BHC	25 or 50	FOR USE IN OVERSEAS ZONES AS A STANDARD APPLICATION FOR TREATING THE INTERIOR OF HOMES IN MALARIOUS AREAS. A suspension formulation is most effective. Dosage and cycle of — retreatment depend on the vector, geographic area, and transmission period. DDT and dieldrin are effective for 6 to 12 months, BHC for 3 months. When the vectors are resistant to these organochlorine compounds, malathion or propoxur should be used. Their efficacy is from 2.5 to 6 months.
			DDT	100 or 200	
			dieldrin	25 or 50	
			propoxur	100 or 200	
CONTINUOUS VAPOR TREATMENT			dichlorvos	1 dispenser per 1000 cu. ft.	Formulated in resin in United States. Dispensers are suspended from ceiling or roof supports. Provides — 2½ to 3½ months of satisfactory kills of adult mosquitoes. Do not use where infants, ill, or aged persons are confined or in areas where food is prepared or served.
				1 dispenser per catch basin.	— Dispensers are suspended 12" below catch basin cover.
OUTDOOR	GROUND APPLIED	SPACE SPRAY		**Lb./acre**	Dosage based on estimated swath width of 300 ft. Mists or fogs are applied during the dusk to dawn period. Mists are usually dispersed at rates of 7 to 25 gal. per mile at a vehicle speed of 5 mph. Fogs are applied at a rate of 40 gal./hr. dispersed from a vehicle — moving at the same speed; occasionally at much higher rates and greater speeds. Finished formulations contain from 0.5 to 8 oz./gal. actual insecticide in oil, or, in the case of the nonthermal fog generator, in a water emulsion. Dusts also can be used. For ground ULV application[c], technical grade malathion is dispersed at a rate of 1 to 1.5 fl. oz./min. and a vehicle speed of 5 mph or at a rate of 2 to 3 fl. oz./min. and 10 mph. For synergized pyrethrins the discharge rate is 2 to 2.25 fl. oz./min. at a vehicle speed of 5 mph.
			carbaryl	0.2-1.0	
			chlorpyrifos[e]	0.0125	
			fenthion[e]	0.001-0.1	
			malathion	0.075-0.2	
			naled	0.02-0.1	
			pyrethrins (synergized)	0.002-0.0025	

(Continued on next page)

[9] ULV as used for labeling purposes is defined as: application of a volume of ½ gallon or less of undiluted concentrate per acre

Table 2 (continued)

Type Application	Toxicant[b]	Dosage	Remarks
		Lb./acre	
	Abate	0.05-0.1	Apply by ground equipment or airplane at rates up to 10 quarts of formulation per acre depending upon concentration employed. Use oil or water emulsion formulation in areas with minimum vegetative cover. Where vegetative cover is heavy, use granular formulations. DO NOT APPLY PARATHION IN URBAN AREAS. For prehatch treatment on an area basis, use methoxychlor (1 to 5 lb./A.) or chlorpyrifos (0.1 lb./A.). Chlorpyrifos and fenthion provide prolonged effectiveness in contaminated water at dosages 5 to 10 times those listed.
	chlorpyrifos[c,e]	0.0125-0.05	
L	EPN[c]	0.075-0.1	
	fenthion[c,e,d]	0.05-0.1	
A			
	malathion	0.2-0.5	
R			
	methoxychlor	0.05-0.2	
V			
I	parathion[c], ethyl or methyl	0.1	
C			
I	paris green	0.75	Apply paris green pellets (5%) at rate of 15 lb./A. with ground equipment or airplane.
D			
E	fuel or petroleum oil	2 to 20 gal./A.	Apply to cover water surface in catch basins or at a rate of 15 to 20 gal./A. in open water courses. With a spreading agent at a rate of 0.5%, the volume can be reduced to 2 to 3 gal./A.

[a] When insecticides are to be applied to crop lands, pasture, range land, or uncultivated lands, consult agricultural authorities as to acceptable compounds and application procedures.
[b] Other compounds, such as Thanite, Lethane 384, propoxur and ronnel, may have uses in certain of the categories mentioned. If so, follow label directions.
[c] For use by trained mosquito control personnel only.
[d] Adhere strictly to label specifications and directions for use.
[e] Not to be applied to waters containing valuable fish, crabs, or shrimp.
[f] Label requires a 3-week interval between applications, except for fog treatments.

centrate of the insecticide is dispensed. Different weather conditions, various types of terrain, and vegetation greatly influence the results of space treatments.

The dosage rate of a space treatment normally is calculated on a pound-per-acre basis for ground treatments and applied on a gallon-per-hour basis with thermal foggers. Ground ULV applications are based on fluid ounces per minute or gallons per hour. Aerial ULV applications are based on fluid ounces per acre. Dosage rates usually are calculated on a determined or assumed effective swath width (normally 200 to 300 feet with ground applications). *The frequency of applications should be based on the need as determined by assessment of adult densities and by other evaluation measures.*

The OP compounds, malathion, naled and fenthion, particularly the first two, are the principal chemicals currently used as ground-applied space treatments. Studies show that there is little difference in the biological efficacy of thermal and nonthermal fogs, nor are "fog oils" superior to diesel oils as a formulation base. ULV ground applications, however, are somewhat less effective than thermal fogs in heavy vegetation as the larger ULV droplets tend to be filtered out more rapidly.

Experiments in west Florida[c] in 1971 with resmethrin (40%), a synthetic pyrethroid, resulted in 93% kill of *C. nigripalpus* at a discharge rate of 1.1 fl. oz./min. at 5 mph and 79% kill at 0.55 fl. oz./min. This compound, however, was ineffective against *Ae. taeniorhynchus*, giving only 28% and 16% kills at the above two dosages. During 1972, a 5% pyrethrum-25% piperonyl butoxide in Klearol formulation at a discharge rate of 2 gph resulted in average kills of caged *Ae. taeniorhynchus* and *C. nigripalpus* of 81 and 96%, respectively, and the same formulation at a discharge rate of 4 gph resulted in average kills of the two mosquito species of 97 and 100%, respectively.

Similar tests with malathion at 1.1, 2.1 and 4.3 fl. oz./min. at 5 mph resulted in 97, 98 and 99% kills of *Ae. taeniorhynchus*. At vehicle speeds of 10 and 15 mph and 3.3 and 4.3 fl. oz./min., 98 and 100% kills of *Ae. taeniorhynchus* were obtained. Against *C. nigripalpus* at 1.1, 2.1 and 4.3 fl. oz./min. and a vehicle speed of 5 mph the average kill was 79, 92 and 98%, respectively; and tests at the 3.3 fl. oz./min. rate and a vehicle speed of 15 mph and 4.3 fl. oz./min., and a vehicle speed of 10 mph gave average kills of 87% and 95%, respectively.

In Georgia ULV malathion applications at flow rates of 3.1 fl. oz./min. and a vehicle speed of 5 mph gave unsatisfactory kills of caged *A. albimanus*, *Ae. taeniorhynchus* and *C. p. quinquefasciatus* in "open sites" at 150 and 300 feet from the machine. When rates were 3.6-4.1 fl. oz./min., kills of 99-100, 82-95 and 84-98% of *A. albimanus*, *Ae. taeniorhynchus* and *C. p. quinquefasciatus*, respectively, were obtained up to 600 feet. The mortalities of the three species obtained with ULV application and with thermal fogs (malathion 6 oz./gal. fuel oil) at 5 or 10 mph at equivalent dosages were essentially the same at "open sites." However, when the mosquitoes were held in wooded areas, fog applications were two to three times more effective. Limited tests in 1971 produced essentially the same results in the same test area. The variation in the flow rates required for a high level of biological efficacy in the studies mentioned previously arises from differences in the test areas, operation of machine and the species involved. The "open sites" in Georgia were more protected than those in Florida, and this factor decreases the effectiveness of either fog or ULV applications. The Chatham County, Georgia, Mosquito Control Commission has found that control effectiveness of ULV treatments is essentially equal to that from fog applications but the former are less costly. ULV applications also do not create a fog hazard to traffic. The primary concern with the ULV mode of application lies in the potentially greater hazard from misuse of the undiluted insecticide concentrate rather than from the misuse of the dilute fuel oil formulation.

Tests were conducted in Minnesota[f] with chlorpyrifos dispersed

with a backpack ULV sprayer. The sprayman walked at a rate of 2 mph and the swath width was 50 feet. Results showed good reduction of *Aedes* spp. 4 hours after treatment at 0.05 lb./A. During 1972 in Minnesota, pyrethrins (12%) synergized at 1 to 5 with piperonyl butoxide and dissolved in light mineral oil was used operationally to treat 31,000 acres with ULV truck-mounted and backpack machines. The rate per acre of actual pyrethrum used was 0.004 lb. Results generally were excellent. Extensive field trials were made with resmethrin in both machines in 1971 and 1972 and good kills were obtained at rates from 0.0025 to 0.004 lb. a.i./A. *D-trans*-allethrin gave decidedly poorer results at rates equivalent to the three toxicants mentioned previously. In all cases the proper amount of concentrate was diluted in a light grade of mineral oil to give the desired number of fluid oz./A. All 24-hour counts were almost back to pretreatment levels due to reinvasion. *Aedes vexans* was the dominant species.

The truck-mounted unit was calibrated to discharge 3 fl. oz./A. at a speed of 5 mph and a swath width averaging 300 feet The median mass droplet size was 8 to 10 microns with a range of 3 to 25 microns. The backpack unit was calibrated to discharge 7 fl. oz./A. with a man walking 2 mph and a swath width of 50 feet. The MMD droplet size was 16 microns with a range of 5 to 47 microns. Five-minute pre-exposure landing counts were made in each test site, followed by 2-, 4- and 24-hour counts in the same spot.

Malathion is labeled for gound ULV use at flow rates up to 1 gph at vehicle speeds of 5 mph and 2 gph at vehicle speeds of 10 mph. A 12% pyrethrins-, 60% piperonyl butoxide-, and 28% mineral oil-formulation also is labeled for ground ULV use at rates up to 0.0025 lb./A. pyrethrins. The label also includes specific criteria relating to droplet size, tank pressure, nozzle elevation and vehicle speed. Failure to adhere to the label specification could result in hazard to nontarget organisms or cause damage to automobile paint; therefore, *ULV applicators are urged to comply fully with the label requirements.*

In California[B], the poor results obtained in applying mosquito larvicides to rice fields and the problem of widespread multiple OP resistance in mosquito larvae have forced a number of mosquito control agencies to increase their dependence on adulticides. Tests during the past 2 years have revealed that the approach works very well in open-field situations, allowing swath widths of a mile or more downwind, but less well in urban situations where structures and vegetative cover afford the mosquitoes' protection.

Ground ULV studies in Arkansas showed malathion, naled and chlorpyrifos to give fair control of adult *Psorophora confinnis*. In Florida, synergized pyrethrins, chlorpyrifos, naled and resmethrin were the most effective of 13 chemicals tested against *Ae. taeniorhynchus*.

In public health work the first applications of the ULV technique were from aircraft. Aerial treatments were shown to be of great value as an emergency measure to curb mosquito densities during natural disasters or disease epidemics.

In 1972 cooperative studies in Haiti between CDC, the government of Haiti and the Agency for International Development demonstrated that aerial ULV applications of malathion at a dosage of 4.5 fl. oz./A. reduced populations of adult *A. albimanus* by more than 99%. Six applications were made to the 20,000-acre study area over a period of 50 days with the first two treatments 5 days apart; the remainder 10 days apart. Each application to the area was accomplished by a single flight just after sunrise on each of 5 days. The swath width used was 300 feet and the aircraft flew at a speed of 140 mph and at an altitude of 150 feet. After the initial reduction of adult densities during the first two cycles, the number of mosquitoes in TDL updraft ultraviolet traps and in biting collections remained at very low levels for the balance of the spray cycles and for a month following the last application. Significant decrease in transmission of epidemic *falciparum* malaria followed the reduction of mosquito populations. Brain cholinesterase levels from birds and other vertebrates collected before and after spray applications showed no significant change.

Critical to the successful use of the ULV technique is the adherence to the basic specifications on droplet size, droplet distribution, and climatic conditions at the time of application. The optimum size of the ULV droplet appears to be about 25 microns MMD; with aerial applications droplets can range up to 50 microns MMD but *greater* sizes should be avoided. Droplets larger than 50 microns represent a waste of material as well as constitute an inefficient particle for producing optimum biological effectiveness. In addition, *the hazard to automobile paint increases with droplet size.*.

Since droplet size, distribution and swath width are influenced by a number of factors related to equipment (*i.e.*, pump pressure, nozzle placement, nozzle size, air speed, etc.), the performance characteristics of the equipment must be assessed thoroughly, including biological evaluation, before it is employed in operatonal treatments. Evaluation must continue during operational applications to insure early detection of trouble due to equipment malfunction. *Currently, only malathion and naled are labeled for this purpose.* The dosage levels are 3 fl. oz./A. for malathion and 0.5 to 1.0 fl. oz./A. for naled. The higher rate for naled applies to terrain with heavy cover.

Aircraft which have been successfully employed for ULV dispersal of pesticides against mosquitoes have normally flown at a speed of 150 mph and 150-foot altitude, producing a swath width of 300 to 500 feet. Greater swath widths have been used successfully with multi-engine aircraft. However, droplet size and density per unit area lose uniformity with increased swath because of natural sorting of droplets with the small droplets falling more slowly and drifting further than the larger droplets.

The data available indicate that ULV treatments should be made during periods when temperatures are below 80° F. or before any temperature inversion occurs. Treatments should be applied only when wind currents are below 10 mph.

In west Florida[C], aerial spray tests of 35% naled in soybean oil applied at an overall volume of 2.8 fl. oz./A. in grouped swaths against salt-marsh mosquitoes resulted in average control of 94% and 68%

after 1 and 2 days, respectively.

Evaluation of the comparative effectiveness of ULV (<7.0 fl. oz./A.) versus conventional aerial sprays (*i.e.*, 3 qt./A.) against salt-marsh mosquitoes showed that naled at 0.2 lb./A. gave similar results with either type of application. Fenthion produced 20% less reduction in landing rate counts at 6 hours with the ULV application than with the conventional sprays, but counts at 24 and 48 hours indicated similar levels with either type of treatment. In Kentucky, propoxur at 0.075 lb./A. and a 2:1 mixture of propoxur and fenthion at the same application rate gave essentially the same level of control of *Aedes sollicitans*. Naled yielded excellent kills at rates of 0.05 and 0.1 lb./A.

Larvicides:

The LC-95 levels for 12 compounds against species of three genera of mosquitoes (Table 3) indicate that different species frequently vary in their response to a toxicant. Carbamate compounds (*e.g.*, propoxur, carbaryl) generally are less toxic to the larvae than the OP insecticides.

The degree of control obtained with larvicide applications often depends upon the degree of pollution and the type and amount of vegetative cover present. Where cover is heavy, it may be necessary to increase the dosage or the amount dispersed to obtain satisfactory results and granular formulations frequently provide better control than emulsions or oil sprays. In heavily polluted water, such as log ponds, a treatment may lose its effectiveness within 48 hours.

In California, resistance has precluded the effectiveness against some *C. tarsalis* and *Ae. nigromaculis* populations of any registered OP or carbamate insecticides at the legal rates of application. In other areas of the State these species have developed resistance to certain OP compounds, notably malathion, fenthion and/or parathion. Resistance in larvae is primarily involved but tests confirm the observation that control of adults is also hampered. In 1969 when chlorpyrifos and fenthion were applied by the ULV technique in California at dosages of 3 to 6 fl. oz./A., the results with each against *C. tarsalis*, the encephalitis vector, were considered excellent. These applications were made as part of an emergency encephalitis prevention program. Helicopter treatments of impoundments of the Tennessee Valley Authority with Abate or chlorpyrifos at 0.004 lb./A. gave excellent control of *A. quadrimaculatus* without marked destruction of nontarget organisms. Each compound was less effective against the culicine larvae than against larvae of *A. quadrimaculatus*. In Minnesota, trials[E] with 2% Abate Celatom granules at 0.03-0.06 lb./A., 10% malathion granules at 0.5-1.0 lb./A., 2% Gardona granules at 0.15-0.20 lb./A., or 1% chlorpyrifos granules at 0.075-0.15 lb./A. gave satisfactory kills of one or more *Aedes* species. Preflood applications of chlorpyrifos granules at 0.2 lb./A. continued to give kills of *Ae. vexans* larvae for periods greater than 60 days. Similar applications[D] of 1% chlorpyrifos granules at 0.1 lb./A. gave satisfactory kills of *Ae. sticticus* and *Ae. canadensis* larvae in woodland pools for at least 4 weeks despite intermittent drying of the pools. Five percent methoxychlor granules applied as a preseason larvicide for *Aedes* control proved to be effective in New York at a dosage rate of 1.0 lb./A.

Small plot tests (CDC) in Georgia of 18 compounds as preflood treatments showed chlorpyrifos (0.5 to 2.0 lb./A.) to be the most effective against *Ae. taeniorhynchus* and *A. albimanus* larvae. At 2 lb./A. it gave 12 weeks of 90% kills of larvae exposed to sod samples treated with granules, emulsions or suspensions. At 4 lb./A. carbaryl was effective for 10 weeks against *Ae. taeniorhynchus* while propoxur (2 lb./A.) and Abate (4 lb./A.) produced 6 weeks of effectiveness. Abate, although equivalent to chlorpyrifos in its toxic effect on larvae (Table 3),is much less effective than chlorpyrifos in the presence of organic matter.

Table 3. LC_{95} levels (ppm) for various insecticides against three mosquito species resistant to organochlorine compounds.

Insecticide	*A. quadrimaculatus*	*C. p. quinquefasciatus*	*Ae. aegypti*
Abate	0.004	0.001	0.004
propoxur	0.5	0.5	2.5
carbaryl	2.5	2.5	2.5
dichlorvos	0.01	0.02	0.1
chlorpyrifos	0.004	0.004	0.004
fenthion	0.02	0.005	0.02
Gardona	>2.5	0.5	0.5
malathion	0.5	0.1	0.5
methoxychlor	0.5	0.5	>2.5
parathion, ethyl	0.01	0.01	0.02
parathion, methyl	0.025	0.005	0.01

In polluted water, chlorpyrifos, fenthion and Abate have proved effective against *Culex*. In Africa, chlorpyrifos was superior to either fenthion or Abate at a concentration of 1.0 ppm. Periods of efficacy of chlorpyrifos have been as along as 144 days in a waste lagoon at 1.0 ppm and as long as 120 days in a Louisiana log pond at 0.5 ppm. In a large scale program in Burma, weekly applications of 0.3% fenthion emulsion were used to treat polluted ditches and cesspools. Over a 3½-year period >95% reduction of *Culex* populations was obtained without any change in the response of the species to fenthion.

In extensive field trials in Puerto Rico, premises treatments with Gardona suspension (2.5%) in urban areas of two municipios controlled *Ae. aegypti* breeding in tin cans, tires and other containers for 8 to >12 weeks. In rural areas no positive sites for breeding were found in the treated containers for 21 weeks. In Florida, methoxychlor (1.25%) gave satisfactory control of *Ae. aegypti* for 3 months and was equal to or better than DDT (1.25%).

Abate at a dosage of 1 ppm (sand granules) has been effective against *Ae. aegypti* larvae in drinking water, in bird baths and in animal watering devices. No accumulative increase of Abate has occurred in water treated at 3- or 6-week intervals nor were any clinical symptoms observed in a village population exposed to such treated water for 1.5 years.

In Thailand a single application

of Abate granules to *Ae. aegypti* breeding-containers drastically reduced larval indices for 8 weeks. These data suggest that successive properly-timed treatments, made 2 months apart, might be a satisfactory preventive regimen for controlling dengue hemorrhagic fever.

Trials in the Canal Zone indicated that two properly-timed ULV applications of fenthion (0.075 lb./A.), which is effective against both larvae and adults, gave long term protection from anopheline mosquitoes provided the area was large enough. Such treatment minimized the possibility of re-infestation by extensive migration which generally did not exceed 0.5 mile.

In California, three applications of chlorpyrifos (1.6 fl.oz./A. to rice fields failed to satisfactorily reduce adult populations of *C. tarsalis* and *Anopheles freeborni*, partly because of migration from adjacent untreated areas even though, in the test area, marked reductions of larvae occurred.

Oil applications continue to be a suitable means of killing mosquito larvae. Fuel oil mixed with 0.1% Triton X-100 and applied at a rate of 2 to 3 gal./A. has been used to treat water areas and marshy areas harboring valuable fish and wildlife.

Applications of Flit M.L.O. at 2-3 gal./A. were effective in operational use in California[B] and have shown promise in Minnesota[E]. The use of fuel oil with a 0.1% spreading agent (T-Det-MC) at 3 gal./A. gave results similar to Flit M.L.O. against *Ae. vexans* in Minnesota[E]. In some localities in California results with Flit M.L.O. at 2 gal./A. have not always been satisfactory for reasons unknown, although lack of penetration through vegetative cover was suspected. Observations indicate that Flit M.L.O. applications at times tended to delay the developmental period of the immature mosquito larvae. Effective kills of salt-marsh mosquito larvae in Georgia marshes also have been achieved with fuel oil and T-Det-MC or Triton X-45 (0.5%) at 4 gal./A. High temperatures and winds may necessitate an increase in dosage to 6 or 8 gal./A.

FLIES

Domestic flies include a variety of species that are closely associated with man, such as the house fly, little house fly, and various blowflies. The breeding sites of these flies are directly related to the occurrence of animal wastes, refuse and other organic debris produced by man so that effective control with chemicals results only when it is combined with adequate sanitational measures.

The house fly, *Musca domestica*, in contrast to blowflies, such as *Phormia regina*, *Phaenicia sericata* and *Phaenicia cuprina*, readily develops resistance to both organochlorine and OP insecticides. Populations of *P. cuprina* and *P. sericata* have developed resistance to organochlorine compounds, but only in areas outside of the United States. With the house fly the problem can be considered as being critical since this species has become resistant to most of the organochlorine and OP compounds generally used in its control. Such resistant populations also are frequently less responsive to carbamate and pyrethrum type materials. The resulting reduction in choice of effective chemicals accents the fundamental necessity of improving environmental sanitation as the primary control means.

Residual treatments:

Although residual applications have long been used for adult house fly control, the resistance factor has rendered overall treatments of this type of little value in many areas. Compounds[10] such as dimethoate (1%), Gardona (2%), malathion (5%), naled (1%), ronnel (1%) and fenthion (1.5%) have been used for this purpose but the duration of their effectiveness as residues has been lessened to such a degree that other types of treatment (space or bait treatments) are more feasible.

Residual treatments are effective against other flies that have resting habits similar to those of the house fly. The little house fly, *Fannia canicularis*, a frequent pest in chicken ranches and dairies in certain areas, is readily susceptible to residual applications of malathion (5%) or ronnel (1%). Deposits of these compounds are relatively short-lived, but each controls *Fannia*. *In making applications on interior surfaces of chicken ranches, extreme care should be taken to avoid contaminating feed and water.* DIELDRIN, LINDANE, DIAZINON AND TRICHLORFON ARE NO LONGER LABELED FOR USE IN POULTRY HOUSES.

Fannia frequently rests out-of-doors on vegetation and exterior walls during hot weather, and treatment should be applied to these surfaces as well as to the interior of the building. In California[B] it is recommended that trees and shrubs located more than 10 feet from the buildings not be sprayed because they serve as primary resting sites for certain natural enemies of flies.

In dairy barns or animal shelters the duration of effectiveness of chemical measures varies from one premises to another, depending on the sanitational practices followed. More frequent treatments with less volume per application may provide satisfactory control, particularly if the initial application is made before optimum fly breeding conditions occur. Successful control has been obtained in Wisconsin dairy barns by applying 5 gallons of 1% ronnel at 2-week intervals or 1.25% dimethoate at 4-week intervals, with the first treatment made at the beginning of the fly season. In Denmark, a 30% coverage with a 1% dimethoate treatment directed at the "preferred" resting sites produced satisfactory to excellent control for 2 to 3 months. In North Carolina, selective applications of a formulation of Gardona-dichlorvos to a poultry farm at intervals of 2 to 5 weeks combined with naled sugar baits gave satisfactory control, partially because *such applications did not affect the predaceous mites in the poultry excreta.*

In west Florida studies[C] have shown that one application of 1% methoxychlor emulsion gave 95% control of the adult *Stomoxys calcitrans* (dog fly) emerging from the grass. This effectiveness extends for more than 30 days, which is longer than the grass remains attractive to the fly. Application to the piles of decaying aquatic vegetation is at a rate of 100 gallons per foot width of grass per mile. Although it is chemically related to DDT, methoxychlor is biodegradable and presents less of a potential hazard to aquatic nontarget organisms than DDT.

Dichlorvos, malthion, naled,

[10]These insecticides have specific restrictions as to the type of food handling establishment and the areas wherein each may be used. Therefore, label directions must be strictly followed.

ronnel, and trichlorfon (Table 4) are labeled for use as baits in dairy barns, but trichlorfon is not registered for use in poultry houses.

Bait applications generally produce spectacular reduction of fly densities within a few hours, but their effectiveness is of short duration unless further treatments are made. Successful use of baits requires diligence in applying them and IN MAINTAINING A REASONABLE DEGREE OF SANITATION.

Permanent bait stations minimize the effort and time required for dispensing baits. Their use also provides continual insecticidal pressure in reducing the fly population. For dispensing dry baits, plywood trays (one to two trays per 1,000 square feet of floor area) are suitable. An effective liquid bait dispenser can be made from a chicken-watering unit modified by inserting a cellulose sponge in the trough to prevent clogging by dead flies. Toxicants such as dichlorvos or trichlorfon at a concentration of 0.1% in a sugar water solution have been used in these units. A continuous source of toxicant can be provided from a dichlorvos-resin strip inserted in the jar.

In Georgia dairies where house fly populations have become resistant to residual applications dichlorvos baits proved to be the only means whereby such populations could be controlled. Control was achieved even against populations that showed a threefold to fourfold resistance to the compound. In Florida, tests showed that house flies from six dairies had resistance to trichlorfon 19 to 138 times that of a susceptible strain, yet 1% trichlorfon sugar baits gave effective control. From such data it is apparent that the exposure route of a resistant insect to the toxicant is an important factor in determining the control efficacy of the compound.

Outdoor space sprays:

Space applications usually are more effective against resistant house flies than residual or larvicide applications with the same compounds, but their cost frequently precludes general use in municipal programs. However, such treatments are warranted at problem sites and in emergencies. Repeated daily applications will be required at problem sites (*e.g.*, refuse dumps), since the efficacy of the spray depends on the insecticidal particles impinging on the fly.

In field tests in Georgia, the pound-per-acre dosages required for effective kills at distances up to 200 feet for six compounds were: malathion >0.6, ronnel 0.4, fenthion 0.4, dichlorvos >0.3, naled 0.1 to 0.2 and dimethoate 0.1 to 0.2.

Quick knockdown sprays, dispersed mechanically or by hand, have been used to some extent by dairy and beef cattle farmers. Deodorized kerosene solutions of ronnel (2%), malathion (2%), or synergized pyrethrin or allethrin (0.1%) applied with an electric mist sprayer against house flies in dairy barns produced 70 to 98% reduction within 10 minutes after treatment. With most applications, not more than 50% reduction was evident 24 hours after treatment even when repeated daily for 5 to 21 days.

Studies at a poultry ranch in Georgia have shown that resmethrin was highly effective in reducing house fly populations. In applications of a resmethrin emulsion by a backpack mist blower, dosages as low as 0.025 lb./A. provided average reductions in grill indices of 95% within 2 hours after treatment. Dimethoate (0.15 lb./A.), naled (0.2 lb./A.) and Gardona (0.2 lb./A.) were less effective; naled gave the highest reduction of 84%.

In Florida, ground applied thermal fogs of propoxur, naled and fenthion (each at 4% in fog oil) gave 98, 94 and 86% kills of caged *S. calcitrans*, respectively. At 1%, propoxur also was superior to naled and fenthion. Malathion was ineffective. At a 12% concentration it produced only a 28% kill. In other more recent tests[c] thermal fogs of propoxur and naled (3.2 and 3.5 oz./gal. in fuel oil, respectively) produced mortalities of caged specimens at or above the 95% level. Treatments are applied in the daytime at a rate of 40 gal./hr. and a vehicle speed of 5 mph or at twice that gallonage and speed.

During the 1972 season[c], ground ULV aerosol applications of resmethrin against caged adult *S. calcitrans* at a discharge rate of 0.53 fl. oz./min. resulted in a 95% fly kill. Tests with malathion applied at a dosage rate of 2.1 fl. oz./min. gave 91% fly kill. Malathion was not effective at a rate of 1.1 fl. oz./min. Treatments were applied at night at a vehicle speed of 5 mph using a ground ULV machine.

Tests of aerial ULV sprays in west Florida[c] of 25% naled by volume in soybean oil applied at an overall volume of 1.3 fl. oz./A. in four 200-foot swaths gave 90% or better kills of caged stable flies in an area 3,000 feet wide downwind. Tests of 40% resmethrin by volume in soybean oil applied at an overall volume of 1.73 fl. oz./A. in these tests gave >90% fly kills an average distance of 1,400 feet downwind. These sprays did not damage automobile paints.

Larvicides:

The control of fly breeding with chemicals normally is relied on in situations where there are accumulations of organic matter, such as animal excreta, garbage, fruit culls, vegetable pulp and carcasses. Such conditions reflect a lack of or a low level of sanitation, since elimination of the organic accumulation would be the logical remedy. Further, the performance of pesticides in such situations is poor because the application frequently fails to penetrate the media to contact the larvae and may also break down rapidly under the moist conditions prevailing therein. In addition, larviciding frequently destroys mites and fly larvae (*e.g.*, *Ophyra*) that prey on house fly larvae or soldier flies which create a medium not suitable for the breeding of *M. domestica*. The value of these natural enemies in house fly control is indicated by data from North Carolina which showed that an integrated control program of poultry manure management and selective adulticiding (see Residual treatments) at 2- to 5-week intervals provided house fly control levels equivalent to those resulting from the weekly application of larvicides. The latter method which destroyed the predaceous mite populations required five times as much insecticide as well as greater manpower than the integrated approach which was not detrimental to the mite fauna.

Most of the OP compounds (Table 4) are toxic to fly larvae, but diazinon has been most effective in initial kill and residual action. The maximum period of residual action of larvicidal sprays is 1 to 2 weeks. In larvicide tests in Florida poultry houses neither dimethoate nor Gar-

dona was effective after 7 days. Dimethoate at 200 mg./sq. ft. gave 7 days of good control of larvae in poultry houses whether applied by conventional spray methods or by low volume, a method in which the undiluted concentrate is applied directly to the droppings. This procedure does not liquefy the droppings as much as do emulsion treatments. Volatile compounds in plastic formulations offer promise for treating larval media. In Florida three applications of dichlorvos pellets applied at 200 mg./sq. ft. of breeding area in poultry houses controlled both house fly larvae and adults for 7 weeks. Monthly sprays of 1 or 2% dimethoate or diazinon to garbage pits in a recreational area in Georgia failed to reduce materially the number of flies trapped from the pits.

The incorporation of insecticides in the feed or water of livestock or poultry is an approach that has been used to prevent or control fly breeding in animal excreta. Numerous compounds have been shown to be effective when so administered but none of the materials is labeled for use as a feed additive for poultry. Coumaphos can be added to cattle feed; when fed to cattle at a level of 144 ppm it produced 94 to 98% mortality of house fly larvae. Aspon (200 ppm) in chicken mash fed to 40 pullets produced good control of house fly larvae but was not effective against *Fannia pusio*. No residues of Aspon were found in the eggs or in the tissues of heart, muscle or fat during the period the chickens were fed treated mash or in the month after treatment was stopped.

In comparative tests of 12 compounds added to poultry droppings and evaluated against larvae of *F. canicularis* in Massachusetts, malathion, carbaryl and dicapthon were ineffective, but initial and short-term efficacy was evident with fenthion, coumaphos, Ciodrin, dimethoate, diazinon, dimetilan, ronnel, trichlorfon and Zytron. Dimethoate was the most effective, producing high mortalities at 1 ppm. Larvae of *F. canicularis* showed approximately 90% mortality when exposed to droppings from chickens whose food contained 125 mg. of coumaphos per kilogram.

In studies with dairy cattle fed 30 ppm of 59% encapsulated Gardona, 100% of the OP-resistant house fly larvae seeded onto the feces were killed. In a field trial, manure from treated cows showed a 94% reduction in fly infestation. Cows fed 60 ppm for 4-6 months showed an average concentration in the feces of 2.24 ppm. Residues in milk were from <0.005 to 0.013 ppm. No

Table 1. Organophosphorus Insecticides Used as Baits, Space Sprays and Larvicides in Fly Control.[a]

(State regulations may impose certain restrictions on the use of these toxicants in dairies or at other specified sites; therefore, the individual should be certain that his usage conforms with local restrictions.)

Type Application	Toxicant	Formulation	Remarks
BAIT	diazinon	1# 25% WP plus 24# sugar; 2 fl. oz. 25% EC plus 3# sugar in 3 gal. of water.	Normal application is 3-4 oz. (dry) or 1-3 gal. (wet) per 1000 sq. ft. in areas of high fly concentration. Repeat 1 to 6 times per week as required. Avoid application of bait to dirt or litter.
	dichlorvos	3-6 fl. oz. 10% EC plus 3# sugar in 3 gal. water.	The use of permanent bait stations will prolong the efficacy of each treatment.
	malathion	2# 25% WP plus 23# sugar.	Available as commercial baits labeled for use in dairies and in food processing plants[b] except at sites where food is exposed. None of these baits should be employed inside homes nor should diazinon and trichlorfon be used in poultry houses. Diazinon also is not to be used in dairy barns.
	naled	1.0 fl. oz. 50% EC plus 2.5# sugar in 2.5 gal. water.	
	ronnel	2 pt. 25% EC plus 3# sugar in 3 gal. water.	
	trichlorfon	1# 50% SP plus 4# sugar in 4 gal. water.	DO NOT CONTAMINATE FEED OR WATERING TROUGHS.

(Continued on next page)

OUTDOOR SPACE SPRAY[c]	diazinon[d] fenthion	11 gal. 25% EC in 34 gal. water.	— Application rate is 15 gal. per mile.
	dichlorvos	6 gal. 50% EC in 44 gal. water.	— Application rate is 15 gal. per mile.
	dimethoate[d]	3 or 6 gal. 50% EC in 50 gal. water.	— Application rate is 20 or 10 gal. per mile.
	malathion	5 gal. 55% EC in 41 gal. water.	— Application rate is 20 gal. per mile.
	naled	1.5 gal. 65% EC in 50 gal. water.	— Application rate is 15 or 20 gal. per mile.
LARVICIDE	diazinon	1 fl. oz. 25% EC to 1 gal. of water.	Application rates are 7-14 gal. per 1000 sq. ft. as a coarse spray. Repeat as necessary, usually every 10 days or less. For chicken droppings, use only where birds are caged. Diazinon is not labeled for use in poultry houses.
	dichlorvos	2 fl. oz. 10% EC to 1 gal. of water.	
	dimethoate	0.5 pt. 43% EC to 2.5 gal. of water.	
	malathion	5 fl. oz. 55% EC to 3 gal. of water.	AVOID CONTAMINATION OF FEED OR WATER AND DRIFT OF SPRAY ON ANIMALS.
	ronnel	1 pt. 25% EC to 3 gal. of water.	

[a] For information on chemicals to be used against livestock and crop pests and for their residue tolerances on crops, consult your State Agricultural Experiment Station or Extension Service.

[b] Includes dairies, milk rooms, restaurants, canneries, food stores and warehouses, and similar establishments.

[c] Based on swath width of 200 ft.

[d] Not specifically labeled for outdoor space applications.

adverse effects on feed intake, milk production or general health were observed.

Technical Gardona in particle sizes of 74 to 177 microns when fed to cows at 4.5 to 36 ppm was more effective against the house fly than particle sizes of <74 microns. In a field trial manure from cows fed 30, 45, 60 and 90 ppm technical Gardona (>74 microns particle size) reduced larval populations by 81, 88, 93 and 98%, respectively. Milk contained residues of Gardona up to 0.015 ppm.

FLEAS

Xenopsylla cheopis (Rothschild), the principal vector of plague, remains susceptible to DDT except in parts of India, Egypt, Thailand and Vietnam. *Pulex irritans* L. have been reported resistant to DDT in Greece, Israel, Turkey, Egypt and South America. Species of *Ctenocephalides* infesting domestic pets and yards frequently cannot be controlled with chlordane and other organochlorine compounds in the United States as well as in French and British Guiana and Colombia.

In overseas areas, DDT (5 to 10%) dust applications to rodent runways and harborages are the chief means of controlling non-resistant *X. cheopis*. Lindane (1%), malathion (3 to 5%), diazinon (1 to 2%) and carbaryl (3 to 5%) should be considered for use against *X. cheopis* populations that fail to succumb to DDT dusts. Application should be thorough to insure adequate contact between the rodent-flea and the dust, since poor control from inadequate dusting can be mistakenly interpreted as resistance to the pesticide use.

The possibility of introducing plague-infected fleas into the United States via containerized cargo from plague endemic areas has led to investigations on suitable chemical control measures. Tests (CDC) conducted on the use of one-half or one dichlorvos-resin strip in "Conex" shipping containers (approximately 300 cubic feet) filled with simulated cargo gave 98 to 100% kills of *X. cheopis* on rats exposed for 48 hours at temperatures of 60°F. or above. Exposures of 6 hours at temperatures of 78° to 86°F. in empty "Conexes" gave average kills of 90% in 24 tests. With a 24-hour exposure at temperatures of 75° to 83°F., complete kills were obtained with one-half or one strip in empty or simulated cargo filled "Conexes." Tests in Florida with dichlorvos indicate that vapor concentrations of 0.25 μg./liter of air for 3 hours produce complete kills of *X. cheopis*.

The potential of high concentrate micronized dusts of various insecticides for use in disinsecting unoccupied aircraft was evaluated in cargo trailers in cooperative tests by the U.S. Department of Agriculture and CDC. Application of micronized dusts of chlorpyrifos (40%), resmethrin (25.5%), chlorpyrifos (20%) + resmethrin (12.8%), chlorpyrifos (13.3%) + resmethrin (8.5%) + propoxur (21.3%), chlorpyrifos (10%) + resmethrin (6.4%) + propoxur (16%) + Gardona (20%), DDT (42.5%) + carbaryl (42.5%), Gardona (80%), propoxur (64%), fenthion (20.2%), *d-trans* allethrin (14%), chlorpyrifos (10%), or fenitrothion (26.1%) at a rate of 2 g. of dust/1,000 cu. ft. produced complete kills of *X. cheopis* except for Gardona (80%), propoxur (64%) and chlorpyrifos (10%) which gave 62, 96 and 91% kills, respectively. Resmethrin (25.5%) also gave complete kills at 1 g. of dust/1,000 cu. ft.

Although human plague has not been a critical problem in the United States in recent years, this disease frequently is common among wild rodents such as prairie dogs and squirrels in the western United States. When epizootics occur among such rodents, the danger of human infection increases greatly. One method of controlling the fleas on these rodents is the use of bait boxes containing an insecticide. When the rodents enter the box to feed, they pick up sufficient insecticide to kill the fleas on them and those living in the nest or burrow. In a plague epizootic among the squirrels in Denver, Colorado (CDC), bait boxes, spaced at 500-ft. intervals, containing 10% DDT and peanut butter gave good control of the squirrel fleas. In trials in Colorado (CDC) 2% carbaryl dust was found to be effective against the prairie dog flea when applied at a rate of 3 oz./burrow. The same dust used in bait boxes containing rolled oats gave 95% control of fleas on deer mice.

Experimental laboratory studies[A] have shown that several OP compounds and mirex are effective as systemics in killing fleas on rodents.

Table 5. Pesticides used on pets for flea control.

Toxicant	Formulation	Percent Concentration
carbaryl	Dip or wash	0.5[a]
	Dust	2.0-5.0[b]
coumaphos[c]	Dip	0.2-0.5
	Spray	1.0
	Dust[d]	0.5
lindane[c]	Dust	1.0
malathion	Dip	0.25
	Spray	0.5
	Dust	4.0-5.0
pyrethrum	Spray	0.2 + 2.0 synergist
	Dust	1.0
rotenone	Dust	1.0

[a] 1.0% acceptable for use by veterinarians only.
[b] Do not use on cats under 4 weeks of age.
[c] Do not use coumaphos or lindane on dogs under 2 months or on cats.
[d] Dust also contains 1.0% trichlorfon.

The lowest percent concentrations of toxicant by weight in the food of the cotton rat/kangaroo rat/cottontail rabbit, respectively, that were effective were: fenthion — 0.15/0.015/0.03; diazinon — 0.03/0.03/0.6 and mirex — 0.06/0.06/0.12. A 0.3% trichlorfon corn-milo bait[A] fed to captive wild cotton rats contained enough vapors in 8 grams of feces to cause complete mortality of *X. cheopis* in 48 hours. Chemical analyses showed that both trichlorfon and dichlorvos vapors were produced by the trichlorfon baits.

The OP and carbamate compounds are the principal chemicals used for the control of *Ctenocephalides* fleas on animals and premises. For effective control of these fleas, treatment of the pet alone is not sufficient, since the animal soon becomes reinfested from the untreated premises. Sleeping quarters, bedding, kennels and other areas frequented by the animal should be treated at the time the pet is disinfested.

Flea infestations on animals can be controlled by the use of the toxicants in Table 5. Resin collars containing dichlorvos have been labeled for use on dogs (except for whippets and greyhounds) and on cats (except Persian). The amount of dichlorvos varies with the size and type of animal involved so proper selection of the collar is important. Cotton webbing collars impregnated with 0.75 to 1.0% lindane may be used on either dogs or cats.

Certain treatments are labeled *for*

application only by licensed veterinarians. Ronnel, as a 0.25% solution, can be used for external treatment (dip or sponge) of dogs and cats. These animals can be treated by oral administration of tablets of ronnel while tablets of trichlorfon or Cythioate can be used for dogs. Dichlorvos (0.02%) and dioxathion (0.2%) are labeled for external use on animals.

For treatment of infested sites inside the house, sprays of diazinon (0.5%), lindane (1%), malathion (2%), or ronnel (1%) can be used as spot applications. Yard infestations can also be controlled by treatment with these compounds at an application rate of 1 gallon per 1,000 sq. ft. Lindane, ronnel and diazinon as 1% emulsions were shown to eliminate infestations for 63 days; whereas with malathion, the effectiveness persisted for 7 days. Propoxur (1%) and fenthion (2%) are labeled for outdoor use by qualified pest control operators. Dusts of malathion (3 to 5%), lindane (1%) and carbaryl (3 to 5%) can be used against flea infestations in yards at application rates of 1 to 2 lb. per 1,000 sq. ft.

BEDBUGS

Resistance to the organochlorine compounds in bedbugs is not a problem in the U.S., but in other parts of the world *Cimex lectularius* L. and *Cimex hemipterus* (Fabr.) populations frequently are resistant to these compounds. *C. lectularius* populations in Israel also have been recorded as resistant to malathion and fenthion. However, the species remains susceptible to diazinon despite 4 years' usage. *C. lectularius*, in USSR, has developed a high level of resistance to trichlorfon.

A single residual application of insecticide emulsion or solution to baseboards, wall crevices, bedsteads and mattresses of infested premises will usually control a bedbug infestation. Sprays containing trichlorfon (0.1%) ronnel (1%), dichlorvos (0.5%) or malathion (0.5 to 1%) are commonly used. Special care should be exercised in the treatment of mattresses and upholstery; only a light application should be used. *Under no circumstances should mattresses be soaked with spray. Infant bedding, including the crib, should not be treated. With dichlorvos or trichlorfon, spray only tufts and seams of mattresses and air until dry — at least 4 or 8 hours, respectively — before reuse.* If the infestation persists, re-treat at not less than 2-week intervals.

Since bedbugs hide in cracks and crevices, adding pyrethrin (0.1 to 0.2%) to insecticidal formulations will increase the effectiveness of the treatment by stimulating the bedbugs to leave their harborages, thereby insuring better contact between the insects and the residual insecticide.

Synergized pyrethrin sprays (0.2% pyrethrins) alone also are effective, but two or more treatments at intervals of 2 to 6 weeks may be required.

TICKS AND CHIGGERS

Ticks are vectors of various rickettsial and virus diseases throughout the world. In the United States, Colorado tick fever and American spotted fever are transmitted by ticks, and tick paralysis is also caused by these arthropods. Chiggers, although involved in scrub typhus transmission in the Far East, are primarily an annoyance to man in this country. Resistance to the organochlorine insecticides has been reported in the ticks *Dermacentor* and *Rhipicephalus* in the United States, but not in chiggers.

The brown dog tick, *Rhipicephalus sanguineus*, frequently causes severe annoyance to man by invading the home and by infesting domestic pets. As the species does not always respond to control by the chlorinated hydrocarbon pesticides, the problem of ridding dwellings of infestations has become more important in recent years. The ticks may be found throughout a dwelling. *Control demands treatment of both the infested premises and the dogs present.* Treat all infested areas thoroughly.

Compounds effective as sprays in treating homes for control of the brown dog tick are propoxur (1%), diazinon (0.5%), dioxathion (0.5%), chlorpyrifos (0.5%), fenthion (1.5%), lindane (0.5%), malathion (1-2%) or ronnel (2%). Dusts containing 5% carbaryl are also effective. The pesticides (except malathion and ronnel) should be employed only as *spot treatments* to baseboards, floor and wall crevices, window frames, and other harborage sites. Re-treatment of the home 1 or 2 weeks later may be required for severe infestations, but a single application will often suffice for light infestations. Five-foot-wide band treatments of 2% daizinon granules (8 oz. per 20 linear feet) around foundations may prevent ticks from entering. Chlorpyrifos granules are labeled for the same purpose.

Careful attention must be given to treating the dog's sleeping quarters and the animal itself. *Propoxur and diazinon should not be used to treat the animal.* However, dust of lindane[11] (1%), carbaryl (5%), coumaphos (0.5%), trichlorfon[11] (1%) and malathion (3 to 5%) can be applied directly to the dog. Liquid washes may give better penetration of the hair than dust; coumaphos[11] (1%), lindane[11] (0.03%), or malathion (0.5%) are suitable. With severe infestations, it may be necessary to re-treat the household and the dog one or more times at weekly intervals. Dichlorvos (0.1%), naled (0.2%), carbaryl (1%), dioxathion (0.15%), or ronnel (1%) may be used as an animal dip by veterinarians. Successful control of ticks on dogs by oral use of ronnel has also been reported by veterinarians.

In treating outdoor areas for ticks or chiggers, avoid application to ponds, streams and other water courses or to their adjacent margins, since at the maximum dosages these pesticides (except lindane) are highly hazardous to fish. Where the use of chlorinated hydrocarbon insecticides is considered a hazard to nontarget organisms, the OP and carbamate compounds should be substituted.

In the United States area control of the various ticks can be obtained by applying chlordane or toxaphene at rates of 2 pounds of toxicant per acre, BHC at the rate of 0.5 to 1.0 pound of the gamma isomer per acre, Gardona, 1 pound per acre, or carbaryl at the rate of 2 pounds per acre. Suspension, emulsion, or dust formulations of these pesticides produce similar results. The level of control secured is dependent on the adequacy of the coverage. In brushy areas, 50 gallons of spray or 40 pounds of dust per acre of the proper concentration are required; approximately half these amounts are needed on thin cover sites, such as lawns. Because certain ticks (*e.g., Dermacentor variabilis*) congregate along roads, paths, and trails, treat-

[11]Do not use on dogs under 2 months of age.

ment may be restricted to these areas. Treatments with these chemicals usually prevent reinfestation for 30 days or more. In overseas areas DDT (2 lb./A.) has proved highly effective against tick-borne disease vectors.

In small plot tests with ground equipment, diazinon, chlorpyrifos and fenthion were equally effective against the lone star tick, *Amblyoma americanum*, when applied at an approximate volume of 8 gallons per acre and dosages of 1 or 2 lb./A. Each compound gave 6 weeks of effectiveness within a range of 89 to 99% reduction. Propoxur, carbaryl, and naled were only slightly less effective. All were superior to malathion which gave poor kills. In small plot tests[p] chlorpyrifos (spray or granules) at 0.25 lb./A. gave satisfactory control for 5 to 6 weeks. Mechanical clearing of nature trails also effectively reduced the number of ticks present. ULV applications of propoxur (0.5-2 lb./A.) with ground equipment reduced the tick populations 89-97% for a 6-week period.

Area infestations of chiggers, such as *Eutrombicula alfreddugesi*, can be controlled with spray or dust treatments of toxaphene or chlordane (1 to 2 pounds per acre), or lindane (0.25 or 0.5 pound per acre). In overseas areas dieldrin at a rate of 2 lb./A. has given greater effectiveness against the chigger vectors of scrub typhus than the aforementioned compounds. Thorough coverage of the area is required.

LICE

The body louse (*Pediculus humanus humanus*), the crab louse (*Pthirus pubis*) and the head louse (*P. humanus capitis*), a subspecies of the body louse, all attack man. The crab louse and the head louse stay on the body continuously, whereas the body louse remains on the clothing except when feeding.

The body louse, the vector of epidemic typhus, becomes a problem primarily among people forced to live under crowded or insanitary conditions such as refugees, migrants, or prisoners.

Insecticidal lousepowders should be applied carefully to the inside surface of the clothing, particularly the undergarments, with special attention given to seams and folds. Usually 1 ounce of powder will suffice for adequate coverage of an individual. Treatments can be applied to the clothed individuals or to the garments.

For mass treatment under epidemic conditions, dusts of DDT (10%), lindane (1%), or malathion (1%) are effective against the body louse. DDT has been the insecticide generally used, but malathion is equal in efficacy (3 to 4 weeks), and a single application normally is effective against both the egg and crawling stages. It is also the insecticide of choice against louse populations in certain areas that are resistant to DDT and lindane. However, recently body louse populations resistant to malathion have been found in Burundi and in Egypt.

Treatments with powders of lindane (1.0%), or synergized pyrethrum (0.2%) or allethrin (0.3%) usually necessitate a repeat application 7 to 10 days later to kill newly hatched lice. Pyrethrum or allethrin formulations are more for individual use than for mass treatments since they tend to clog mechanical application equipment.

Field tests have shown that single applications of 2% Abate or 1% malathion were equally effective in controlling DDT-resistant body lice for at least 25 days. Whether Abate can be of value against malathion-resistant lice is yet to be determined. The Burundi malathion strain, when colonized and selected with malathion, showed cross resistance to several carbamate and OP compounds and a slight tolerance to Abate was apparent.

Head lice infestations have been a serious problem among school children in England for more than 5 years. Although DDT and lindane have been effective for controlling such infestations, populations resistant to these compounds have now developed. Malathion has proved to be an effective substitute. In trials where 3,000 individuals were treated with an 0.5% malathion lotion, no live lice were recovered the day after treatment and ovicidal action was complete.

In the United States, problems with head lice have occurred more frequently in recent years, particularly among school children. Shampoo and lotion preparations are more acceptable than dust since the latter suggests that the person is infested with lice. The preparations available to the public contain synergized pyrethrins. Those available *by prescription only* contain lindane (1%) or benzyl benzoate (12%):benzocaine(2%):DDT (1%). To obtain the full benefit of the application, the treatment should remain in the hair as long as possible in accordance with label directions. Malathion as a liquid preparation is not labeled for use in the United States.

Crab lice can be controlled by dust applications of the same insecticides used for body louse control. Persisting infestations should be retreated at 1- to 2-week intervals. Label directions on some of the lotion preparations for control of head lice indicate that they may also be used against crab lice.

COCKROACHES

Blattella germanica (L.), the German cockroach, is the principal species associated with man and is of greatest concern because of its widespread distribution and its ability to develop resistance to many of the insecticides used for control purposes. Although populations resistant to diazinon, fenthion and malathion have been detected in several parts of the U.S., the OP pesticides are used routinely for control purposes. Malathion resistance appears to be specific but diazinon resistance extends to related chemicals. A strain slightly resistant to propoxur, a carbamate, also has been reported from Louisiana. Despite the occurrence of OP resistant populations in certain localities, such resistance has not, as yet, created a widespread control problem.

The pesticides usually employed in cockroach control are given in Table 6. Because cockroaches frequent areas where food is prepared or served, precautionary measures should be taken in making the insecticide treatment to avoid contamination of food or food preparation surfaces. Specific precautionary restrictions are placed on compounds when they are applied in *food processing plants, restaurants and other areas where food is commercially processed or prepared.* Residual applications can be used in the inedible product areas of food processing plants and restaurants but are not to be applied in the edible product areas or in serving areas while food is exposed. Pre-

cautionary wording to this effect is stated on the preparations registered by EPA for this purpose. Precautionary wording also is included on labels for nonresidual type insecticides, vaporizing type compounds, baits, etc.; hence the applicator must adhere closely to the label instructions in making his treatment.

In treating households or food handling establishments with a residual insecticide, the toxicant should be applied as a spot treatment. The spot spray should be used to treat baseboards, cabinets, along water pipes, under refrigerators, behind stoves, and other cockroach harborages. To obtain a quick kill in heavy infestations or to drive the insects from protected areas a pyrethrum aerosol should be used just prior to the residual treatment.

The activity of insecticidal residues is markedly influenced by the type of material to which the formulation is applied. Compounds that are somewhat volatile persist longer on painted metal surfaces than on unpainted metal, whereas the reverse may be true with other toxicants. Formulations also may influence the efficacy of insecticide application. Emulsions generally have a longer residual life than solutions. In addition, certain solvents, masking agents and emulsifiers exert a repellent effect on *B. germanica* as shown in laboratory tests with treated and untreated panels in which a greater number of specimens frequented the untreated surfaces. Such data indicate that the so-called inert ingredients in a formulation could have a decided influence on the performance of products containing the same toxicant.

In simulated harborage studies (CDC), 2/3 of the wall surfaces of test boxes were treated with propoxur, chlorpyrifos, or diazinon. Exposure of *B. germanica* to residues (50 mg./sq. ft.) of the three compounds at 30-day intervals indicated chlorpyrifos was superior to diazinon and propoxur. Chlorpyrifos gave 57, 19, 57, and 60 weeks of 90% kills on painted and unpainted metal, masonite and tile, respectively. When the wall coverage was reduced to 1/3, the period of residual activity decreased for each of the three compounds approximately 33 to 50%, emphasizing the importance of adequate coverage in obtaining successful control.

Table 6. Insecticides employed in cockroach control.

Insecticide	Formulation	Percent[a] Concentration
propoxur	Spray	1.0
	Bait	2.0
diazinon	Spray	0.5[b]
	Dust	1.0[b]
dichlorvos	Spray	0.5
	Bait	1.9
chlorpyrifos	Spray	0.5
fenthion[c]	Spray	2.0
Kepone	Bait	0.125
malathion	Spray	5.0
	Dust	5.0

[a] Maximum allowable.
[b] 1.0% spray and 2.0 to 5.0% dust for pest control operators only.
[c] Pest control operators only.

Field tests with 1% solution of fenthion gave more than 90 days effective kills, whereas the dust formulation (3%) was effective for 30 days. Diazinon dust (2%) gave excellent results for this same time period. In public housing projects in California 1% emulsion of propoxur virtually eliminated heavy cockroach infestations in apartments but odor and staining problems occurred. In Florida, buildings infested with *B. germanica* and treated with 1.0% propoxur emulsion still showed 89% reduction in population at 120 days.

Over a period of time some insecticide baits used for cockroach control lose their effectiveness. In tests (CDC) dichlorvos bait after 6 weeks gave 68% kill of *B. germanica*, whereas propoxur and Kepone baits continued to give more than 90% mortality after 101 days. Dichlorvos and propoxur possess fumigant action, but Kepone does not. For quick kills, dichlorvos is superior to Kepone and propoxur but when long-term action is desired it is inferior. Baits applied in combination with spot residual treatments may be more effective than either application alone. Baits composed of 0.125% Kepone in a paraffin base were shown to eliminate *Periplaneta americana* breeding in sewer lines within 2 weeks.

Dust applications offer an advantage over liquid treatments in that they give better penetration of enclosed areas, such as beneath cabinets and in wall voids. Their use in visible areas is normally precluded because of their unsightly appearance. The drift qualities of dusts enable them to be used in any area that is difficult to spray. A disadvantage, however, is that cockroaches tend to avoid dust deposits. Certain dusts containing fluoridated silica aerogels are reported to act as a desiccant as well as a repellent to cockroaches.

Studies with boric acid solution (CDC) applied to 2/3 of the simulated harborage at 200 mg./sq. ft. showed only 18% kill over an 18-day test period but with boric acid powder applied to ½ of the simulated harborage, 90% kills were obtained for >14 weeks. Two formulations of silica aerogel and 2% diazinon dust under the same exposure conditions were not effective for more that 2 weeks. The poor kills resulted from the specimens tending to avoid the dusted harborage. Boric acid dusts have been used successfully against *B. germanica* infestations in dwellings and commercial buildings in California.

In cooperative tests with the U.S. Navy on seven ships, 0.5% chlorpyrifos emulsion applied to the food service areas gave an average reduction in the infestations of 90 to 99%. Propoxur (1.0%) emulsion applied in four ships decreased the infestations 10 to 63%. However, this same insecticide applied as a 1% solution in a commercial preparation produced 94 to 97% reduction of the *B. germanica* populations in three ships. Other tests with the U.S. Navy were conducted aboard eight submarines that were treated with dichlorvos aerosol (6.5%) at a rate of 12 oz./10,000 cu. ft. Three of these vessels also were treated with 2% propoxur bait. Greater than 97% control was achieved with all dichlorvos treatments. The propoxur (2.0%) bait used to control newly hatched nymphs from eggs unaffected by the dichlorvos resulted in excellent control for 2 months after the aerosol application. Air samples taken aboard three of the submarines indicated that after 4 hours of ventilation the dichlorvos concentrations in the vessels fell

rapidly to low levels of <0.2 μg./liter of air.

VENOMOUS ARTHROPODS

In recent years public awareness of venomous arthropods has increased greatly, partially because of a greater trend toward outdoor living and recreation. The venomous arthropods possess various mechanisms (stings, bites, urticating hairs, etc.) that normally are employed in capturing prey or as a means of defense. However, when they enter homes or when people invade the natural habitats of these arthropods, the contact between man and the arthropod may result in a severe allergenic and anaphylactic response in some individuals. Marked discomfort and even death can result from the toxins injected by the arthropod. Medical attention is the initial step in aiding persons stung or otherwise contacted by a venomous artropod, but chemical control is of much value as a preventive measure.

Scorpions:

Scorpions, particularly in the southwestern U.S., are quite dangerous to man. The elimination of hiding places, such as boards or lumber piles, accumulations of debris or stored material in basements minimize the risk of scorpion stings. Chemical measures within dwellings should consist of spot treatment of baseboards, under furniture, closets, crevices, around plumbing or any areas where scorpions are observed. Attics and crawl spaces or basements should also be sprayed. Residual sprays containing 1-2% carbaryl, 2% chlordane, 0.5% dieldrin or 5% deodorized malathion may be applied with hand or power sprayers. Dusts containing 2% carbaryl, 5% chlordane, or 1% dieldrin also are suitable. The residual life of chlordane or dieldrin dusts make them particularly suitable for treating wall voids. Dusts (1%) or sprays (0.5%) of lindane tend to excite scorpions, thus increasing the danger of stings.

Outdoor structures such as outbuildings, with surfaces in contact with the soil should be treated to a height of 2 feet above grade. Hiding places, such as stacks of lumber, debris, or firewood, also must be treated. For this purpose use sprays of carbaryl (2%), chlordane (2%), or dieldrin (0.5%), or dusts containing 10%, 10% and 2%, respectively, of these materials. Granules of diazinon (10%) also are effective for area treatment.

Spiders:

Of particular concern to man are the so-called widow spiders (*Lactrodectus* spp., especially *L. mactans*, the black widow spider) and the "brown" spiders (*Loxosceles* spp.). Although the black widow spider has long been considered the most important venomous spider in the U.S., the brown recluse spider, *L. reclusa*, has assumed importance in recent years. The toxin of the latter species kills the tissue around the bite, a condition termed "necrotic arachnidism."

The black widow may enter homes, but is usually found in outdoor harborages, such as privies (particularly under the riser), woodsheds and other outbuildings, stacks of old lumber or brick and trash piles. This spider is attracted to the moisture around water meters and may be found in basements. The brown recluse spider and its relatives favor storage areas, such as closets and attics. They may inhabit stored clothing, packing boxes and similar places, also hiding in cracks, crevices and other dark recesses of buildings. In addition, the brown recluse spider frequents transformer boxes of utility companies.

Control may be achieved by eliminating or by treating the harborage sites with spot applications of sprays containing malathion (2-3%), chlordane (2%), propoxur or ronnel (1%), diazinon (0.5-1%), and dieldrin or lindane (0.5%). The brown recluse spider is significantly repelled by malathion. Dusts of chlordane or malathion (5%) or of fluoridated silica aerogel may be used in attics, crawl spaces and voids. Creosote has been used successfully on the wood of outhouses to kill or repel spiders.

Space treatments of dichlorvos or pyrethrins (0.5%) from aerosols or ground equipment kill spiders but exert little or no residual effect.

Wasps and related insects:

Wasps (yellow jackets, hornets, cicada killers) build nests in or around dwellings — beneath eaves, on porches or other structural surfaces — or in trees, shrubbery, rock fences and in holes in the ground. Nests, close to dwellings or in shrubbery, pose a particular problem to children. Direct treatment of nests with insecticide is the method commonly used to control these pests, whereas baits are feasible for treating larger recreational or surburban areas.

Liquid formulations of the following materials may be used to control these pests: propoxur (0.5%), carbaryl (2%), diazinon (0.5%), dichlorvos (1%) and malathion (2%). Use water-based sprays to avoid damaging vegetation. Dust preparations of carbaryl (5%), chlordane (3%) or lindane (1%) are suitable.

The insecticidal sprays or dusts are best applied at night or early morning when the wasps are less active and are in or on the nests. Emphasis is placed on treating the nest opening. In the case of underground nests, the opening should be covered with soil after treatment.

In recreational or camping areas insecticide baits are exposed in protected dispensers placed at ground level, in tree axils or suspended from tree branches. The dispensers are constructed so that the bait is inaccessible to children and other nontarget animals. Control of ground nesting yellow jackets in California has been reported by the use of baits — mirex (0.5%) in fish flavored cat food or chlordane (0.5%) wettable powder in suitable meat bases. Bait dispensers should be located no more than 200 yards apart at a minimum density of 1 per 2 acres and may require weekly servicing. With increased density of bait dispensers to 2 per acre, frequency of exposure can be reduced to 3 alternate days per week.

RODENT CONTROL

Three species of rodents live in close association with man, the Norway rat (*Rattus norvegicus*), the black or roof rat (*R. rattus*), and the house mouse (*Mus musculus*). Rats serve as an integral link in the transmission of plague and endemic typhus; man becomes infected with such diseases through the bite of certain fleas associated with these rodents. Rat-bite fever, salmonellosis and leptospirosis are other infections associated with rats. Rickettsial pox, a mite-borne infection of man, is carried by mice. In

addition to the disease aspect, rats pose a critical problem in many cities by biting persons, particularly infants and invalids.

Rats thrive wherever ample food and harborage are available — conditions that may exist in and around homes, restaurants or other food-handling establishments. Deficiencies in the handling and storage of human as well as animal food and refuse and in building construction foster the propagation of rodents. Community sewage systems have been found heavily infested with rats whose movement to above-ground harborages may cause a public health problem. Such invasions have led to city-sponsored programs to control rat infestations in sewers.

Successful rat control can be achieved only by diligently practicing proper refuse storage, collection and disposal, and food storage, harborage elimination and ratproofing. Rodenticides are *supplemental to* and *not a substitute for* good management.

Rodenticides fall into two categories: the single-dose type which is fatal to the rat through a single feeding (*e.g.*, zinc phosphide, red squill) and the multiple-dose type which requires repetitive feedings to be effective (*e.g.*, warfarin, diphacinone). The latter type has dominated the field of rodent control for more than a decade. These slow acting rodenticides are used in most situations because of their effectiveness and low level of hazard to human and domestic animals.

Multiple-dose rodenticides:

Anticoagulant poisons include pindone, warfarin, diphacinone, and Fumarin, each of which can be used as a liquid or dry bait. Dependable control of the Norway rat and the roof rat generally can be accomplished with these rodenticides at the concentrations indicated in Table 7.

Laboratory tests (CDC) with a new anticoagulant, chlorophacinone, have given promising results against Norway and black rats. In free-choice tests of treated and untreated ground laboratory chow, containing 0.005% cholrophacinone, complete mortalities of *R. norvegicus* and *R. rattus* were obtained in an average of 7.3 and 9.2 days, respectively.

The cumulative rodenticidal action of the anticoagulants depends upon consumption of at least a small amount of the poison almost every day for several days. To achieve effective control, anticoagulant baits must be available to the rats for at least 2 weeks. Establishment of permanent bait stations in places subject to continued reinfestation gives good control, provided old baits are periodically replaced with fresh ones.

Table 7. Multiple-dose rodenticides employed against mice and commensal rats.

Rodenticide	Percent Concentration	
	Mice	Commensal Rats
chlorophacinone	0.2[a]	0.005
diphacinone	0.0015-0.005	0.0015-0.005
Fumarin	0.001-0.025	0.001-0.025
pindone	0.015-0.025	0.015-0.026
warfarin	0.001-0.05	0.001-0.05

Dilution factors:
0.05% (500 ppm) = 1 part of 0.5% concentrate to 9 parts of bait.
0.025% (250 ppm) = 1 part of 0.5% concentrate to 19 parts of bait.
0.01% (100 ppm) = 1 part of 0.5% concentrate to 49 parts of bait.
0.005% (50 ppm) = 1 part of 0.5% concentrate to 99 parts of bait.
0.0015% (15 ppm) = 1 part of 0.5% concentrate to 297 parts of bait.

[a] Used as a tracking powder.

Resistance to the anticoagulant rodenticides has been found in Norway rats in Europe since 1958, with resistant populations occurring in Wales, England, Denmark, and Germany. Warfarin-resistant roof rats also have been found near Liverpool, while resistant house mouse populations have been detected in England and near San Francisco in this country. The resistance mechanism involved usually relates to the anticoagulants as a group adversely affecting the clotting ability of blood rather than to chemical composition. However, in England and Denmark some rats, although resistant to warfarin, pindone and other anticoagulants, still remain susceptible to coumatetralyl, a hydroxycoumarin. Until 1970 anticoagualnt resistant populations had not been found in the United States despite the widespread use of these rodenticides. Now, however, field reports and laboratory tests confirm the existence of anticoagulant resistant populations of Norway rats in New Jersey, New York, Washington, D.C., Idaho, Georgia, Illinois, Virginia, Wisconsin, and North Carolina. Other resistant populations also may exist in this country. However, until resistance is confirmed in a population and the use of anticoagulant baits obviously fails to give adequate control, the operator should not discontinue their usage.

In accordance with the finding that resistance to anticoagulants is becoming widespread, it is apparent that present practices of relying continually on anticoagulant baits in rodent control should be modified. One suggestion is to alternate the use of anticoagulants with that of acute toxicants to reduce the chances of a rat population becoming resistant to the anticoagulants. Acute toxicants could be used to obtain initial reductions of heavy infestations after which anticoagulant baits could be applied to control the survivors. A further, and perhaps sounder, approach would be to place greater emphasis on good sanitation pracitces and to use the anticoagulants only when needed.

Single-dose rodenticides:

The single-dose or "direct" rodenticides are especially useful for the rapid reduction of large populations of rodents. This group of rodenticides generally requires fewer man-hours to apply and less bait material. Included in this group are sodium fluoroacetate (1080), fluoroacetamide (1081), norbormide, red squill, ANTU, and zinc phosphide (Table 8).

Sodium fluroacetate and fluroacetamide are each highly toxic to man and animals. THEIR USE IS RESTRICTED TO APPLICATION BY HIGHLY TRAINED PERSONNEL. The precautions necessary for safe use of 1080 are described in the manufacturer's instructions. The same precautions are applicable to fluoroacetamide. Both

of these rodenticides are useful against rat infestations in sewers, with fluoroacetamide being registered solely for this purpose. Solid baits as well as water baits of fluoroacetamide should contain 2% toxicant. Baits of 1080 should be formulated at 0.2-0.3%.

Norbormide is highly toxic to rodents of the genus *Rattus*, particularly the brown or Norway rat. It is less effective against the roof rat and is non-toxic to mice. Its extremely low toxicity to other mammals and to birds allows its safe use in the presence of pets, livestock and poultry. This rodenticide is labeled at the 1% level for use against Norway rats. Field studies in Georgia with commercial products generally have given unsatisfactory results against Norway rats. However, when norbormide was experimentally prepared with yellow corn meal, good control was achieved on seven of eight rural premises.

Microencapsulation of norbormide has been attempted in an effort to improve its acceptability to Norway rats. Laboratory studies in England indicated that although a greater amount of microencapsulated toxicant was ingested, increased kills did not always result. In Georgia tests (CDC) with microencapsulated norbormide, a greater intake of bait and an increase in the toxicity of the norbormide to rats were obtained. Presumably, the variation in findings have arisen from differences in the microencapsulation procedures which are quite critical to the successful use of the bait.

Fortified red squill, 1 part thoroughly mixed with 9 parts of meat or fish, is appropriate for use against Norway rats where there is a risk of human exposure. Since rats tend to develop shyness to red squill baits, it may be desirable to delay reapplication for at least 6 months. One operational program reports the successful use of frozen red squill baits. The red squill-fish-corn meal torpedoes were kept frozen until they were distributed in the field. Acceptability and rodent kill were satisfactory.

Currently registered concentrated active ingredients of red squill may be applied at 3.5% or 5.1% in baits. One such formulation was studied in southern Georgia. Reacceptance as well as initial acceptance and kills were far superior to those obtained with fortified red squill.

Table 8. Single-dose rodenticides used against rats and mice. (The individual should be certain that his use of any of these rodenticides conforms with the regulations of the state concerned.)

Rodenticide	Concentration (%) in Baits		
	Rattus norvegicus	*Rattus rattus*	*Mus musculus*
ANTU	2.0-3.75[b]	[a]	[a]
arsenic trioxide	1.5[b]	1.5[b]	[a]
fluoroacetamide (1081)	2.0[c]-3.0[b]	2.0[c]-3.0[b]	[a]
norbormide	1.0[b]	[a]	[a]
phosphorous paste	1.38-3.0[b]	1.38-3.0[b]	1.38-3.0[b]
red squill (fortified)	3.5-10.0[b,d]	[a]	[a]
strychnine	[a]	[a]	0.3-0.5[b]
sodium fluoroacetate (1080)	0.2-0.39[c]	0.2-0.39[c]	0.2-0.39[c]
zinc phosphide	1.0-2.0[b]	1.0-2.0[b]	1.0-2.0[b]

[a] Not used against these species.
[b] Solid.
[c] Liquid baits.
[d] The percent concentration used depends on the toxicity of the fortified red squill, i.e., a formulation with an oral LD_{50} to rats of 500 mg./kg. would be prepared at the 10% level.

ANTU also is toxic to Norway rats, but it is not effective against roof rats. ANTU should not be used on any rat population more than once a year because of bait refusal and the development of a tolerance to the toxicant. The compound also has been applied at a concentration of 20-25% as a tracking powder but this method is resorted to only when ANTU baits are not feasible. *ANTU is quite toxic to dogs, cats and hogs.*

Zinc phosphide is effective against rats and mice and has been used extensively as a rodenticide. Baits of 1% zinc phosphide are prepared with meat or with diced fresh fruit and vegetables. It is a stable compound and shows only slight loss of toxicity (<30%) on vegetable and fruit baits over a 90-day period. The gray color of this rodenticide and its strong garlic odor apparently make it somewhat unattractive to nontarget animals. The value of adding tartar emetic to zinc phosphide baits to decrease their potential hazard is questionable. The response of humans to tartar emetic is variable, and including it in the baits adversely affects acceptability to rats. Emphasis should be placed on the careful placement of baits where they are not radily accessible to children, dogs, cats, etc. Any unconsumed baits should be retrieved and destroyed within 48 hours after distribution.

All uses of thallium-based rodenticides were cancelled by EPA in 1972. This compound is extremely hazardous, not only to the user but also to domestic animals, from the standpoint of secondary poisoning.

Gophacide[12], an organic phosphate, is highly toxic to a variety of rodents and has shown definte promise against domestic rats and mice. Few data are available on the response of domestic animals except chickens which are relatively unaffected. In field trials in Georgia (CDC), Gophacide (0.25%) baits of yellow corn meal, hamburger or dog food gave good control of Norway rats on four premises. Fair to good control was achieved in 7 of 10 trials with 0.5% Gophacide-yellow corn meal baits. In 6 of the 23 tests with suitably accepted baits, poor results were obtained. Against roof rats, 0.5% Gophacide baits of yellow corn meal or oatmeal produced good kills on four test premises. Satisfactory control of house mice was obtained on four premises with 0.5% Gophacide in oatmeal, yellow corn meal, or horse feed. No adverse effects on pets or domestic animals were noted in these field trials.

Arsenic trioxide and phosphorous paste, though still available for control of rats and house mice, generally have poor acceptance.

Under certain conditions, the fumigation of rat burrows is useful in reducing Norway rat populations. However, a single treatment may reduce the population only 50%, and unless the fumigation

[12]This compound is currently labeled for use by trained personnel against pocket gophers as a 0.2% bait but is not labeled for domestic rodent control.

is repeated or supplemented by other rodenticidal measures, the reduction is of a temporary nature. Chemicals which have been widely used for this purpose include calcium cyanide powder, chloropicrin, and ethylene dibromide. Such fumigants should be used only by trained personnel.

Baiting:

Since the successful use of rodenticides depends on the acceptability of the bait to the rat, bait formulation often is the critical element involved. The operator may be forced to use a "trial and error" approach in finding a bait acceptable to a specific rodent population. Attention should also be given to the variability of response in rodent populations even in adjacent locations.

Yellow corn meal is a readily accepted inexpensive bait material that can be used as the initial bait in rodenticide operations. If a baiting problem develops, other cereals or bait combinations can be tried. Materials, such as bacon, salmon, rolled oats, sugar and corn, and mineral or salad oil, are frequently included in baits. The addition of liquids to baits containing acute poisons increases acceptability especially where water is not readily available. Tomatoes may be of value as baits under such conditions. Laboratory and field tests in England indicate Norway rats prefer oatmeal to other milled cereals. Up to 50% corn meal can be substituted for the oatmeal without decreasing its attractiveness. The addition of peanut oil up to 8% increased the acceptability of the 50/50 mixture of corn meal and oatmeal to both rats and mice. Baiting problems may be related to the food available to the rats rather than to the rodenticide employed. Improper distribution or placement of the baits may also contribute to failure to achieve satisfactory control. Therefore, a thorough knowledge of the habits of the rodent is essential for successful control operations.

In contrast to the anticoagulant baits which in effect serve as their own "pre-baits" maximum effectiveness and efficiency with "direct" toxicants often require a program of prebaiting in which a choice of several bait materials without the toxicant is offered to the rodents one or more nights prior to poisoning. This procedure permits the selection of the best possible bait for each situation, the most effective bait sites and the proper amount of bait to use, thereby preventing either gross over- or under-baiting. This prebaiting technique also decreases the suspiciousness of the rodents, and they may therefore accept the poisoned baits much more readily.

Under conditions where food is readily available to rodents at all times, *e.g.*, in food warehouses, none of the cereal baits may be accepted; a more productive approach may lie in the use of water baits. The inclusion of sugar (5%) as an attractant has improved the results when other sources of water were removed.

The presence of moisture, either as water or high humidity, frequently causes deterioration of semi-permanent baits. Workers have found that such breakdown can be retarded by mixing the bait with melted paraffin at a ration of 2:1. Such weather resistant baits have been reported effective against both rats and mice. Paraffin bait blocks are of particular value against rat infestations in sewers, but the blocks may mold and become less acceptable to the rats because of the extreme moisture conditions.

House mice:

Control of mice sometimes can be accomplished by the use of anticoagulant baits. Because mice do not forage widely, the use of many well distributed small baits is preferable over a few large ones. The tendency of mice to nibble when feeding requires the use of a higher concentration of anticoagulant (Table 7) to reduce control failures. Preliminary tests in England indicate that an increase of the warfarin concentration to 0.2% does not reduce the palatability of a bait, provided peanut oil is added. Mice are not attracted to old baits, so frequent renewal of baits is desirable. Water baits of anticoagulant rodenticides have been considered as feasible for mouse control. However, the water requirements of mice are low, so such baits are not considered useful.

Strychnine baits (0.3-0.5% strychnine) also are used against mice. Because it is highly toxic, strychnine and the finished bait should be handled with care.

DDT powder (50%)[11], formerly the principal tracking powder used against mice, is no longer labeled for that purpose in the United States. Red squill also has been tried as a tracking dust against mice. Laboratory tests (CDC) with reground red squill (500 mg./kg.) have shown better kills than obtained with the standard red squill. Observations indicate that high humidity causes the red squill to cake, thereby decreasing its effectiveness.

[11]For use by pest control operators and trained personnel.

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Agricultural Chemicals and Public Health

By WAYLAND J. HAYES, Jr., M.D., Ph.D.

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POTENTIAL HAZARDS as well as obvious benefits to the public health result from the manufacture and use of agricultural chemicals.

Among the hazards are the excessive exposure of workers who manufacture, formulate, or apply the materials; the accidental exposure of children or other irresponsible persons; and the exposure of the general population in the event that residues on food should ever be allowed to approach the toxic level.

However, few accidents occur if instructions for the use of the chemicals are followed and the prescribed precautions are taken.

The public health benefits from the use of agricultural chemicals should always be kept in mind in considering the potential hazards involved in the use of these materials. These benefits include improved nutrition and shelter, which result from increased production of food and fiber. Furthermore, some of the so-called agricultural chemicals have fostered health through the control of malaria and other vector-borne diseases (*1*). Certain fertile areas, notably the Pontine Marshes in Italy, which once were practically uninhabitable because of malaria, now support healthy farm families and a thriving agriculture. In many other areas where farming has been carried on for centuries, the health of the farmers has been improved since the use of insecticides (*2*).

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Toxicology of Agricultural Chemicals

The results of using cottonfield insecticides in the Mississippi Delta were investigated by Fowler (*3*) to determine whether the large-scale use of the newer insecticides presented a toxic hazard to the population of that region. The study area included one small city where questions similar to those raised by Biskind (*4–7*), Biskind and Bieber (*8*), Merkin (*9*), and Scott (*10*) had been asked by one physician. It was suggested that insecticides might be at least the contributing cause of fungus infection, hay fever, asthma, sinusitis, gastrointestinal upsets, dehydration, alkalosis, malnutrition, pneumonitis, cancer, poliomyelitis, arteriosclerosis, heart disease, and insanity.

All physicians in the study area were urged through their medical societies to report cases of suspected insecticide poisoning. Other groups, including hospital staffs, county agricultural agents, and civic clubs, were approached for the same purpose. As was anticipated, a few cases of acute poisoning by parathion and several chlorinated hydrocarbon insecticides were reported and a few others were uncovered by Fowler in an epidemiological survey of 83 farm laborers and a survey of 639 unselected persons living on a large plantation. The cases of poisoning were all caused by excessive exposure to the insecticides and were frequently associated with gross carelessness on the part of workers.

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In addition to direct clinical studies, Fowler reviewed school attendance records, mortality records of the delta and of the State as a whole, and morbidity records of a plantation hospital. He also sought the expert judgment of county health officers. He compared the incidence of disease in these areas during the periods before and after the introduction of the newer agricultural chemicals. He also compared the incidence of disease in the regions of the State of Mississippi where insecticides are little used with the disease incidence in the delta, where cotton culture necessitates the extensive use of agricultural chemicals. In all of the studies, no evidence could be found that pesticides were the direct or indirect cause of any chronic disease or a contributing factor in diseases generally recognized as having other etiologies.

In Washington State, although no cotton is raised, many of the problems faced by orchardists around Wenatchee are similar to the problems faced by cotton farmers in places where the fields are near many residences. Agricultural chemicals must be used extensively in order to produce marketable apples and cotton, and there are many situations in which agricultural lands adjoin the suburbs of a town.

Sumerford and his colleagues (*11*) studied the cholinesterase response and symptomatology from exposure to organic phosphorus insecticides in the Wenatchee district. Emphasis was placed on parathion and tetraethylpyrophosphate because preliminary evidence indicated that these compounds were frequently the cause of illness among workers who used them. However, DDT was usually included in the formulation with these compounds. The amount of DDT used was considerably greater than the amount of organic phosphorus insecticides (*12*) employed in spraying fruit trees, and the clinical studies gave an opportunity to detect injury from DDT if such injury existed.

The persons studied were divided into eight groups. Three groups (mixing-plant personnel, commercial applicators, and part-time applicators) had extensive exposure. Two other groups had definite, although often minimal and irregular, exposure. A sixth group was made up of residents who lived in or near orchards but had no known occupational contact with insecticides; actually, most of them lived in orchards with trees on two or three sides of the house. A seventh group was composed of persons who lived more than 500 feet from orchards and had no occupational contact with insecticides. The eighth group included persons living completely outside of the fruit-growing areas.

The average cholinesterase values for groups of persons known to have definite and consistent exposure to insecticides showed significant reduction during the period of contact. No significant reduction in cholinesterase values was found for the groups who made little or no use of the compounds. Although extensive day-to-day exposure was regularly associated with reduced blood cholinesterase, the only fatal and near-fatal cases found were associated not with long-standing use but with brief, massive exposure.

Although a considerable number of mild illnesses caused by organic phosphorus insecticides were found, it is important that even these mild illnesses followed extensive occupational use of insecticides. Further study by investigators at the Wenatchee Field Station has confirmed that persons who live near orchards do not get enough incidental exposure to cause illness. Moreover, the slight illnesses which workers did get as the result of overexposure were not capricious; they resembled severe poisoning in every way except that they were briefer and milder. Thus, the findings of Sumerford and his colleagues (*11*) confirm the findings of Fowler (*3*).

Classification of Hazards

Hazards associated with agricultural chemicals may be classified as follows:

1. Hazards of manufacture or formulation.
2. Hazards of mixing or application.
3. Hazards to persons not directly associated with the chemicals.
   a. Children and irresponsible adults.
   b. Persons whose food is contaminated by residues of the chemicals.
   c. Persons exposed incidentally.

Fowler (*3*), in his study in a cotton-growing area, encountered accidents involving mixing and application of insecticides and two cases of

U. S. Department of Agriculture photograph.

U. S. Department of Agriculture photograph.

mild poisoning associated with the direct application of parathion to a house.

Sumerford and his colleagues (*11*), working in another area where insecticides are used extensively, found cases of poisoning in all three classifications, specifically, in formulators, applicators, and children who accidentally ingested insecticides.

It should not be supposed that these studies indicate any basically new development. Poisoning in all of these classifications has long been known for the older pesticides. Each chemical carries its own peculiar danger. Both acute and chronic lead poisoning are well-recognized clinical entities. Chronic lead poisoning, either mild or severe, is less frequent than in the past. However, lead poisoning has been reported (*13*) since the introduction of the newer insecticides, and whenever lead is used it presents a constant danger. Pyrethrum is in a completely different class so far as toxicity and hazard are concerned, but to emphasize that no material is safe under all conditions, it need only be recalled that pyrethrum has been the cause of anaphylactic reactions.

Compared with the older materials, the safety record of the newer agricultural chemicals is good (*14*). However, human cases are on record of essentially uncomplicated, acute poisoning by the following newer agricultural chemicals: chlorinated hydrocarbon insecticides—aldrin, chlordan, DDT, lindane, and toxaphene; organic phosphorus insecticides—demeton (Systox), Isopestox, paraoxon, parathion, and tetraethylpyrophosphate; and rodenticides—sodium fluoroacetate (1080), and warfarin. Moreover, the heavy metals may be as dangerous when used for new purposes as they were for old purposes. We have records of poisoning by arsenicals used as herbicides and by mercurials used for fungicidal seed treatments.

Accurate diagnosis of poisoning by newer agricultural chemicals has been made possible by a study of human cases. Obviously, severe poisoning is more easily diagnosed than mild involvement, but except in very specialized situations, diagnosis presents no problem in industry and agriculture or among children who accidentally ingest pesticides. In these instances, the problem, although relatively small, is clearly recognized. Steps to reduce it to a minimum are in order.

Greater emphasis needs to be given to the importance of careful reading of labels. The labels, which are subject to State and Federal control, are the product of careful thought. Accidents with pesticides which do not involve a violation of the instructions and precautions on the label are extremely rare. However, the mere reading of labels is not enough. Each agricultural laborer must be made to understand the reason for precautions in handling insecticides. Proper training may present very real difficulty when laborers are illiterate or when there is a language barrier between them and their supervisors. However, adequate training is the moral responsibility of the employer and the foreman. Such training will be rewarded by fewer accidents and less economic loss.

Recent studies in the Wenatchee, Wash., area

(*15*) indicate that the potential hazard of parathion to spray personnel is greater by the dermal than by the respiratory route. This finding provides a stimulus for more widespread use of protective clothing, but it does not in any way lessen the need for the use of respirators by persons engaged in parathion application. Particulate matter generally is irritating to the respiratory tract, and this alone is adequate reason for wearing a respirator during mixing operations and in other situations involving a high dust concentration.

Accidents to Children

It is easy to say that potentially dangerous materials, whether aspirin or rat poison, should be kept out of the way of children, but to accomplish this requires continued education and constant attention. In many areas, more children are poisoned by kerosene than by any other single material, and additional cases of poisoning are caused by solvents in paints and polishes. As a class, drugs cause more poisoning, both fatal and nonfatal, in the household than other chemicals, the number being about equal to the number of cases involving all other kinds of chemicals common in the household (*16*). The fact that pesticides as a group cause fewer household accidents than some other materials offers little comfort. The record shows that in most instances in which children have been poisoned by pesticides (lindane, parathion, tetraethylpyrophosphate, sodium monofluoroacetate) the tragedy involved a child of the person who owned the compound.

Over and above the personal tragedy, poisoning in children is interrelated with other problems involving hazards to third persons. Once an accident has occurred, the injury to public relations has been done. Recently, two children were killed by ingesting tetraethylpyrophosphate (TEPP). As a direct result of their deaths, the Technical Development Laboratories at the Communicable Disease Center has received correspondence inquiring why the use of such a poisonous material as TEPP is permitted. It is unreasonable to expect the general public to know that this particular chemical hydrolyzes rapidly after it has been applied to fruit trees and that when it is used properly it presents no residue problems. Furthermore, most organic phosphorus insecticides do not hydrolyze so rapidly, and under practical conditions a few of them remain active for months.

The potential hazard of residues of chemicals in foods has little relation to food products obtained from cotton. It is true that cottonseed oil is extensively used as food and that cottonseed meal is used as feed for livestock. However, the residues of most agricultural chemicals remain external on the plant, and the systemic organic phosphorus insecticides have been proved not to be a practical problem so far as cottonseed is concerned.

Incidental Exposure

The potential hazards from incidental exposure to pesticides require special consideration. By incidental exposure is meant any exposure which is neither voluntary nor strictly accidental. Thus, incidental to treating a crop, some pesticides may fall in neighboring fields or suburbs without there being any intent to treat those areas and without there being any accident in the usual sense.

Evidence has been presented by Fowler (*3*), Sumerford and his associates (*11*), Barnes (*17*), and others that under ordinary conditions persons exposed incidentally to pesticides do not contact enough of the materials to cause any injury. However, complaints continue to be heard from certain areas. These complaints show a striking variation from one locality to another, and they appear to bear no strict relationship to the amount of pesticides used in the area or, in fact, whether pesticides are used at all.

One community reached near hysteria largely because it was suspected that the deaths of two infants were caused by incidental exposure to organic phosphorus insecticides. Spraying and dusting of trees had been done in the neighborhood and the odor of insecticides was evident. Epidemiological and clinical studies by the Public Health Service failed to show evidence that incidental exposure was the cause of disease. Alarm was dispelled, although the study did reveal cases of poisoning associated with occupational exposure, and investigation was made of several cases in which children swallowed poison with fatal or near-fatal results (*18*).

Soil Conservation Service photograph.

In two other instances, complaints apparently could be traced to a single person in each community. A study in one community and a public explanation in the other served to reduce the complaints, if not to eliminate them completely. However, an investigation or a public statement will not solve each local problem. In one State, although complaints are less frequent, they have continued after a joint investigation of the use of pesticides by the Public Health Service and the State health department.

It is doubtful if any single reason for success or any single reason for failure to reduce these complaints can be found. For several years, the natural tendency to blame certain illnesses on pesticides has been aggravated by articles in magazines and newspapers, which have failed to recognize the fact that, in large populations, poisoning can be expected to appear most quickly, most frequently, most diversely, and most severely in those persons most extensively exposed to these compounds. The factory workers and farmers who come in contact with chemicals constitute large populations, and it is significant that the cases of poisoning which have occurred were almost all acute and were all the result of definite exposure.

The varied claims of injury from incidental exposure to agricultural chemicals present a problem which can be met chiefly by correct diagnosis of each case. The fact that the studies made so far have failed to reveal injury from incidental exposure to these chemicals does not necessarily indicate that injury would not be revealed under different conditions. In any event, careful diagnosis of each case of suspected insecticide poisoning and a reasonable regard for the principles of epidemiology remain a crucial responsibility of every physician, whether he be in private practice or in the practice of public health.

Community Approach

From the community standpoint, there is a mature and an immature approach to the use of agricultural chemicals. Maturity may be measured by the degree to which citizens are aware of the different factors influencing the community and the degree to which they cooperate for the mutual good. In the mature, basically agricultural community, the necessity for using agricultural chemicals is accepted, as is the potential danger which some of these materials bring to those who use them. Partly because this problem of hazard to the worker has been met forthrightly, the safety record is good. Each grower takes direct, personal responsibility for the chemicals to be used and the amount, method, and timing of their application. Neighbors are advised when insecticides are to be applied and recognize the necessity for their use.

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Observe the rule

An Ounce of Prevention

when using the new insecticides

By **WILLIAM M. UPHOLT**
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THE newer insecticides have been a great boon to the production of more and better fruit. But there are hazards that accompany the use of such materials, particularly when they are misused. Each year there are several deaths from insecticides, especially the newer organic phosphorus compounds such as parathion and tetraethyl pyrophosphate (TEPP). These deaths are usually the result of carelessness or accident.

The first requirement in the safe use of insecticides is that they be stored under lock and key. They must be kept away from children. Empty containers must be promptly and effectively destroyed or locked up. Several deaths have resulted from children playing with "empty" insecticide containers.

Insecticides are not equally dangerous, though all are capable of seriously damaging man, if mishandled. Generally speaking, the organic phosphorus compounds are more dangerous than DDT and its relatives, but this is not always true. Some of the newer non-phosphorous materials are potentially very dangerous, whereas the evidence at present is that some of the organic phosphorus compounds such as malathion or chlorthion may be no more dangerous than DDT.

Many of the older insecticides such as nicotine, hydrogen cyanide, and the arsenicals are as dangerous as some of the newer ones, and if less is said about them it is largely because these materials are not now so widely used. In all cases of doubt it is better to be too careful than not careful enough.

The most dangerous of the organic phosphorus compounds in general use include TEPP, parathion, and demeton (trade name, Systox). These materials and others like them are effective against insects and poisonous to man and animals because they inactivate an enzyme known as cholinesterase. This enzyme has an important function in the nervous system at many locations in the body, including those which control breathing and heart beat. It is normally present in the body in such excess quantity that the body can function normally even in the face of appreciable cholinesterase destruction.

Blood Test

There may be no warning symptoms of poisoning until after a critical amount of the enzyme has been destroyed. The determination of cholinesterase activity by a blood sample is a good test of serious exposure to these insecticides even in the absence of symptoms.

Routine cholinesterase determination is a good method of checking

(*Continued on page* 40)

The RIGHT way and the proper clothing.

The WRONG way and improper clothing.

Reprinted from May 1955 issue of AMERICAN FRUIT GROWER

AN OUNCE OF PREVENTION

(*Continued from page 39*)

the adequacy of safety precautions. If such routine tests show a gradual reduction in cholinesterase activity, it is a good indication that something is wrong and the manager or other responsible individual should immediately find the source of exposure and eliminate it.

Normal cholinesterase values vary widely among individuals. For this reason it is very desirable for anyone anticipating exposure to these insecticides to have his own normal cholinesterase values determined before exposure.

If an individual is poisoned to such an extent that symptoms develop and the cause is confirmed by a blood test, he should avoid any further exposure until another blood test shows that his cholinesterase has returned to nearly his own normal value. Once the cholinesterase activity has returned to normal (within 4 to 6 weeks), the patient has completely recovered and thereafter is no more susceptible than before his first exposure.

Protective Measures

Considerable evidence obtained under actual conditions of use indicates that skin exposure is more hazardous to the operator than exposure by other routes. It is true that dusts or fumes will be very rapidly absorbed if inhaled. Dusts, including the dust cloud that may rise when dumping a wettable powder into a spray tank, are apt to be quite dangerous. The newer "antidusting" wettable powders greatly reduce the danger of inhaling serious amounts of such materials while loading spray tanks, but they do not eliminate the danger.

If parathion or TEPP is to be applied as a dust, a respirator of a type approved by the USDA should be worn. Each of them requires a different type of respirator at present, though efforts are underway to develop a respirator that will be effective against both parathion and TEPP. In either case the filters and cartridges must be replaced regularly according to the schedule suggested by the manufacturers.

While spraying with a large volume sprayer (500 gallon or more per acre) a worker receives much more of the spray material on his skin than through his nose. A sprayman wearing a shirt with short sleeves and an open neck can get a dangerous amount of parathion or similar materials on his hands, arms, face, and neck during the course of an 8-hour day. Therefore, it is important to wear proper protective clothing during spraying operations. Waterproof clothing should be considered mandatory, as should a bath at the close of each day's work, and a clean change of clothing every day.

All users of insecticides should wash carefully and thoroughly before eating, drinking, or smoking since insecticide that is swallowed acts very rapidly. Death has occurred almost instantaneously after a small amount of TEPP or parathion was swallowed.

A similar amount on the skin might also be fatal eventually if allowed to remain but the slower penetration rate allows some opportunity to wash off the insecticide and to get to a physician for treatment. Always wash off immediately any material spilled on the skin!

Symptoms

The early symptoms of poisoning by organic phosphorus compounds are giddiness, headaches, nausea, vomiting, excessive sweating, and tightness of the chest. Not all of these symptoms may be present, but two or more of them should be considered cause for concern, particularly if coupled with known recent exposure.

These symptoms may be followed or accompanied by blurring of vision, diarrhea, excessive salivation, watering of the eyes, and twitching of muscles. By the time any of these latter symptoms appear, the situation is likely to be critical and to justify emergency measures.

Late signs are rattling in the chest, foaming at mouth, convulsions, coma, loss of urinary and bowel control, and respiratory failure.

A supply of 1/150 grain atropine sulfate tablets should be available for emergency use. These can be obtained only by prescription. The physician issuing the prescription should be reasonably familiar with treatment of such poisoning cases and should be contacted promptly if any atropine is taken. Atropine should never be taken until after symptoms of poisoning appear.

Persons developing the more severe symptoms of poisoning should be taken to a physician or medical facility immediately. As implied above, respiratory failure is apt to be the direct cause of death. Therefore, the patient should be watched carefully, and if breathing stops or if he turns blue, artificial respiration should be administered at once. Even if artificial respiration should delay arrival at the doctor's office or hospital, it is more important that respiration be maintained. THE END

LIFE-SAVING SUGGESTIONS ON HANDLING PARATHION OR TEPP

. Or, What can Parathion or TEPP Do to You*

PB 277 666

By Dr. William M. Upholt, *Senior Scientist in Charge, U. S. Public Health Service, Wenatchee Field Station, Wenatchee, Washington*

36

Parathion and tetraethyl pyrophosphate are so widely used that nearly all growers have been exposed to one or the other or both at one time or another. It is logical therefore for the grower to ask, "How has it affected me? Have I been permanently harmed? Can I be poisoned and not know it? Will I be more susceptible next time? How rapid and complete is recovery?"

Dr. William M. Upholt

There are many reasons why every fruit grower needs to know the answers to these and related questions. These answers may affect his own practices in handling organic phosphorus insecticides; they may affect his relationship to his neighbors who may be exposed to the drift from his sprays; they may affect his ability to keep a satisfied crew working for him in spite of their concern for the spray materials.

Satisfying Answers

For these and other reasons every fruit grower owes it to himself to be somewhat of an authority on this subject. Fortunately there are satisfying answers to most of these questions on the organic phosphorus compounds and they are reasonably easy to understand without a college degree in pharmacology.

First, is the question of whether your exposure is significant. It must be assumed (let us hope the assumption is justified), that you have read even the small print on the label. You know therefore that these materials can be rapidly absorbed through the skin as well as through breathing or through the mouth. You know that you should wear protective clothing and should burn or destroy empty containers.

You May Not Be Sick

But you also know that in spite of all these precautions you do get spray on you, and some drifts on to your family and over to your neighbors. You know that other spraymen have not always taken these precautions and they (as far as you know) were not made sick.

Yes, there is no doubt about it in spite of all precautions you will get some exposure and it is possible to get quite a little exposure without feeling sick. But you must also know that quite a few careless spraymen have been made sick and an occasional one has died from parathion poisoning. Why?

In the first place, most spraymen who have been made sick were well aware of their exposure. If you follow recommended procedures or even if you fudge on them a bit but are reasonably careful, your exposure will not make you feel ill.

Margin Provided For Safety

Recommended procedures are designed to give you a margin of safety. If in driving you exceed the safe speed limit, or jump a red light, or fail to signal a turn, it does not mean that you are certain to have an accident. Nevertheless, those safe driving regulations are wise to follow for they greatly decrease the chances of accident.

Similarly, following recommended procedure with insecticides does not insure against accidents nor does their violation guarantee poisoning. Following them will essentially assure against poisoning *barring accident* and so they should by all means be followed.

If you have been seriously poisoned by these insecticides you will know it. First, you will know when you are exposed—it was when the spray hose burst and soaked you, or perhaps when you sprayed into the wind because it was the only way you could get the job done on time, or possibly when you went to thinning the day after the orchard had been sprayed.

Blood Sample Is Taken

Then the nausea, the tightness of the chest, the twitching eyelids or blurred vision and one of the symptoms by itself you might have ignored, it might have been caused by a cold or mild touch of flu, but getting two or three or four of them a short time after exposure leaves little question.

If there is any question the doctor can take a blood sample and send it off for cholinesterase determination which will prove it without a shadow of a doubt.

Suppose you did not have any of the symptoms that the label says go with poisoning, but you did have an exposure you could smell the parathion (you should be able to smell an amount so small that a chemist cannot detect it in the laboratory), you could feel the drift on your skin, or possibly you spilled some on you but washed it off right away.

Could you be poisoned and not have any symptoms? The answer is yes and in some unusual situations without symptoms you might be very seriously poisoned in the sense that even a little more exposure might kill you. But the latter situation is rare. How then is it possible to be poisoned without symptoms?

The answer lies in cholinesterases, the enzymes in your blood that the doctor wants tested. Cholinesterases occur not only in blood, but more important, they bathe all of your nerves where they join the muscles, particularly the muscles controlling your breathing, your digestive system, and other so-called "involuntary" muscles.

They are essential to the proper functioning of these nerves, for without their "dampening" effect, the nerve would discharge continuously without interruption.

Here Is The Picture

Fortunately there is a great excess of cholinesterase in all of the tissues concerned so that much of it can be destroyed without affecting the functioning of the nerves at all. However, if too much is destroyed the nerves are over-active with the resultant headache, nausea, etc., and if a little more is destroyed, the normal nerve function is destroyed entirely and death results.

This, then, is the picture of what happens when you are exposed to any of the organic phosphorus insecticides. The insecticide is absorbed through your skin, through your stomach even faster, or through your lungs almost as fast as if it were injected into your veins.

When it reaches your blood and the nerve endings, it somehow ties up some of the cholinesterase. Some of the newer and safer organic phosphates apparently break down rapidly and release cholinesterase before much damage can be done, but not so with others, including parathion and tetraethyl pyrophosphate.

Cholinesterase Replaced

With these, when the cholinesterase is tied up it seems to be permanent and the body just has to get along without that cholinesterase until it can manufacture some more. If your exposure is very slight and infrequent, the body will replace the cholinesterase fast enough that even blood tests will not detect the loss.

If your exposure is greater, the loss of cholinesterase may be sufficient to notice it in a blood test, but still there may be plenty for proper nerve function. If so, you have been poisoned, but you have no symptoms and if you avoid further

*From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Atlanta, Georgia.

TOXICOLOGY SECTION

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exposure, your body will rapidly replace the cholinesterase and you will soon be back to normal, none the worse for the exposure.

How much depletion can you stand without feeling symptoms? It varies with different individuals. In fact the amount of cholinesterase activity in the blood of normal people varies so much that one may have twice as much as another and still both be perfectly normal.

Variation Quite Wide

In fact, there is no evidence that the latter is any more susceptible to poisoning than the first. In general it is believed that a man can lose up to 30% of his normal cholinesterase without feeling any symptoms. Of course to know how much he has lost you must know his normal value since one man may lose half and still have as much as another man who has lost none.

It is for this reason that you should know what your normal cholinesterase value is if you expect to handle large quantities of these insecticides.

Many Factors Involved

If a man loses 50% to 70% of his cholinesterase activity it is reasonable to presume that it will begin to affect his nerve functioning so that he will have some symptoms and know that he has been poisoned. From there on actual values are pretty much guess work because there are so many factors involved, people vary in their reaction, and our testing techniques are less accurate.

Probably about 80% depletion represents serious poisoning and if it is much greater than that the patient is not apt to live without prompt medical attention, though some men have been known to survive over 90% depletion and in at least one case a man had nearly 90% depletion as a result of long continued exposure without any symptoms other than pin-point pupils and a feeling of fatigue.

However, when this man handled another few loads of 4% parathion dust he went to the hospital in a coma and no one expected him to survive, though he did.

Atropine Helps Temporarily

The label says atropine is an antidote. What does atropine do? It does not destroy the parathion nor does it restore the cholinesterase. It simply takes the place of the cholinesterase in the nerve ending temporarily. Therefore, it may permit the nerves to continue functioning more or less normally until the body can manufacture more cholinesterase.

It is for this reason that taking atropine tablets will not prevent your getting sick. Atropine may make you feel better, but if you are absorbing a lot of parathion it goes right on destroying the cholinesterase even while you are feeling fine. Then when the atropine wears off, you may find yourself in a really critical situation.

Be Sure To See A Doctor!

That is why you should never take atropine until you feel sure that you are sick enough to go to the doctor—*and then be sure to go to the doctor.* You should then be kept under close medical observation until after the atropine has worn off—probably 12 to 24 hours, or until a blood test has proved that your cholinesterase is near normal.

Can you be made ill by parathion without having a lowered cholinesterase activity? Doubtless the answer is "yes," but it has to be qualified. If a person has asthma, breathing dust with or without parathion may make that asthma worse. It is even possible that some individuals may be allergic to parathion though such cases have not been described in medical literature so they are probably rather rare.

Person Feels Just As Sick

In any case if such illness or aggravation is caused by parathion it would be caused by low exposures that would doubtless have no effect on cholinesterase. Again, have you ever been made ill by the smell of ether, or some other substance that has bad associations for you? If someone on a plane gets air sick and vomits, others are very apt to be made sick just by the sight or smell.

The same thing may be true with some individuals with insecticides. True, you may say it is their imagination, and well it may be; your family doctor may call it "psychosomatic." But nevertheless, mental or not, they are sick, and in a sense it is caused by the insecticide but without any lowering of cholinesterase activity.

Public Relations Involved

Actually this matter of psychosomatic, or illnesses falsely attributed to the effects of insecticides should not be "sold short." It may be very important in your ability to get along with your neighbors, to maintain a satisfied work crew, and even to fight restraining legislation.

Thus you should realize that in the modern world of ever-increasing tensions there are many psychological ills that are very real to the sufferer. To dismiss them as mental does not satisfy the patient. It is natural to want to place the responsibility on a physical cause.

Moreover, many minor ailments such as virus infections of the upper respiratory tract cannot be diagnosed specifically short of a laboratory workup that would amount to a research project (and incidentally may produce symptoms similar to parathion poisoning).

"What Now?" You Ask

Again the patient wants to know: "Why am I ill? What caused this illness?" If the doctor cannot tell him, the patient tends to attribute it to something that seems reasonable, and if he has just been exposed to an insecticide, that seems reasonable. Thus, an adequate knowledge of how parathion works and how it affects you may permit the fruit grower to do an important job of public relations.

Having been once poisoned and having recovered to the best of his knowledge, the fruit grower wants to know: "What now? Am I more susceptible than before? Should I avoid all exposure in the future? How serious are repeated poisonings?"

We must admit that all the answers to these questions are not known. Whether or not repeated poisonings may have some permanent effect, perhaps unassociated with cholinesterase effects, time alone can tell.

However, there is no good reason to believe that they will. It is more reasonable to expect all effects to be through the medium of cholinesterase and as indicated above these effects are quite well understood.

Several Cholinesterases

There are several cholinesterases. One type is found in the blood plasma. It is manufactured primarily in the liver at such a rate that even with serious poisoning it is back to normal levels in about two to three weeks, barring further exposure.

Another type is found in the red blood cells. It is apparently manufactured in the bone marrow the same as the red cells themselves. At least it is replenished at about the same rate as red cells, which means that in serious poisoning it may require six to eight weeks to return to normal.

In general the important cholinesterase found in the nerve endings behaves just about the same as that in the red blood cells though it is not known for sure where it is manufactured.

Most Symptoms Soon Gone

It is known that within 48 to 72 hours after serious poisoning, the nerve cholinesterase is regenerated enough so that in most cases all or most of the symptoms of poisoning are gone even though the red blood cell level is still very low.

This would imply that the nerve cholinesterase regenerates at least as fast and probably faster than that of red blood cells. So all the evidence is that recovery even from serious poisoning is complete within six weeks or two months if there has been no more exposure.

Moreover, evidence with experimental animals indicates that they are no more susceptible to poisoning after several episodes than they are the first time they

are exposed. Limited experience with humans indicates that this is doubtless true with man also.

Dangerous State Approached

There is, however, evidence as suggested above that man may not show symptoms as soon if he has repeated small exposures as following one heavy exposure. Thus, a man who uses it daily through the season, as for instance a commercial applicator, and who is careless in his handling of parathion may gradually deplete his cholinesterase to very low levels without feeling sick and thus without realizing it.

Nevertheless his cholinesterase is just as low as if he had been having warning symptoms and a little more exposure may tip the scales to make him critically ill before he knows it. For such a man there is no substitute for frequent blood tests to make sure he is not getting an overexposure.

Wait Until You Are Recovered

Even in such a case, once his cholinesterase recovers completely (which should be not more than six to eight weeks) he will be no more susceptible than before, and if he can correct his carelessness that caused the heavy exposure in the first place, he should not hesitate to return to the job.

The most important warning to him is to avoid all exposure until he has recovered and then find and eliminate the source of the overexposure before he returns to work.

In conclusion it might be pointed out that we tend to fear those things we do not understand. Thus, it is wise for a fruit grower to understand the dangers of organic phosphorus insecticides so that he may respect them instead of fearing them.

You Will Be Less Concerned

If he understands that there is little evidence of their causing any harm other than through their effect on cholinesterase, then he will be less concerned about the trivial exposures he occasionally encounters through drift or otherwise while spraying with normal handling precautions.

On the other hand, if he understands that it is normal for the body to have a great excess of cholinesterase over the amount necessary for proper nerve function, then he will also realize that it is possible for him to have enough exposure to cause serious lowering of cholinesterase without feeling ill at all.

He will thus realize the importance of routine blood samples during continuing exposure even though he feels perfectly well; but that such blood samples do not prevent serious heavy exposures resulting from the occasional accident.

Can Start Out Normally

He will realize that if he feels ill after a known heavy exposure he should have his blood checked. He will also know that if he has several of the known symptoms he should get to a doctor at once and not rely on self-medication even though he may take atropine on the way to the doctor.

After being seriously ill, he will not expect to go back to spraying as soon as he feels well again, but will allow one to two months for recovery and preferably will have a blood test to be sure he is back to normal.

Finally, he will realize that after several months of no exposure he will start every spray season just as normal as if he had never been exposed before.

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PESTICIDE
PUBLICATION

9. SAFETY PROBLEMS RELATED TO TRANSPORTATION AND STORAGE OF TOXIC PESTICIDES

582

*by Homer R. Wolfe**

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Anyone involved in the industrial production of pesticides should have some knowledge about the potential hazards during transportation and storage of toxic chemicals. There has been increasing concern about health problems arising from spillage of toxic pesticides on loading docks, in storage warehouses, ships, lorries, railway cars and other conveyances. Therefore, it is important that every effort be made to ensure safe transportation and storage of the compounds until their delivery to the consumer.

A number of incidents which have occurred during recent years point out the seriousness of this problem (see chapter 1). In the Middle East during 1967, two separate incidents of endrin leakage onto sacks of flour in the holds of ships resulted in a total of 26 deaths and more than 800 illnesses in persons who ate bread made from contaminated flour.[1] In Mexico in 1967, sugar and flour contaminated with parathion caused 16 deaths and many illnesses;[2] in Colombia during the same year, 63 persons died and 165 became ill from eating food made with flour contaminated with parathion during transportation by lorry.[3] In Canada two children were seriously poisoned by sleeping in flannelette sheets that had become contaminated with parathion in the hold of a transatlantic ship.[4]

In the United States there have been a number of spillage incidents. One of the more serious spillages resulted in contamination of a bundle of cotton trousers with the highly toxic organophosphate compound mevinphos. The trousers had been shipped in the same lorry as the pesticides.[5] Six children became poisoned

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through wearing the trousers before investigators located the entire consignment and withdrew it from the market. In Texas during 1968, six members of a family became seriously poisoned when they ate tortillas made from flour contaminated with the organophosphate compound carbophenothion.[6] The flour had been purchased in an unlabelled 100-lb paper bag from a railway salvage store. Flour samples from the family bin contained 3,220 ppm of the pesticide. In another incident oxygen respirators became contaminated with the chlorinated hydrocarbon pesticide endosulfan.[7] The pesticide and the respirators were being transported on the same truck. Containers of the pesticide broke, and the pesticide dust entered the uncovered ends of respirator tubes. The firms involved voluntarily corrected the problem. Another incident involved contamination of biscuits by the organophosphate compound azinphosmethyl.[8] Contamination occurred when bags of the pesticide were loaded on a lorry beside the biscuits. Pesticide dust migrated to the food packages. A shipment of 150 cases of biscuits had to be destroyed.

The provision of information on the toxicity and hazard of pesticides, as well as safety rules for their storage and transportation, is important in minimizing accidents. Furthermore, guidelines are given to those involved in clean-up operations after an accident has occurred.

The United States Department of Transportation has domestic shipping regulations in effect which are designed to prevent contamination through leakage.[9] These regulations require that any such poisonous materials (Class B poisonous liquids or solids) must not be transported in the same vehicle as any foodstuffs, feeds or other material intended for consumption by humans or animals unless the items are packaged in air-tight, non-permeable containers. Any vehicle used to transport such poisons must be inspected for contamination before reuse; in instances where leakage or spillage has occurred, the shipper of the material must be immediately notified for instructions concerning the best method to be employed for removal of the contamination. Any vehicle found to be contaminated must not be returned to service until the contamination has been removed. The last statement excludes vehicles used solely for transporting such poisonous materials.

Even though these regulations are in force, spillage accidents continue to occur. The importance of reporting such incidents cannot be stressed too often.

HANDLING OF PESTICIDE SPILLAGE

When an accident occurs, the primary requirement is an evaluation of the toxic hazard of the pesticides involved. Some pesticide chemicals have a relatively

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[6] Hatcher, R., M. S. Dickerson and J. E. Peavy (1968) United States Public Health Service, National Communicable Disease Center, *Morbidity and mortality Weekly Report*, 5 October, p. 376.

[7] *United States Food and Drug Administration Papers* (1968) Vol. 2, No. 4, p. 31.

[8] Stringer, J. G. (1968) *United States Food and Drug Administration Papers*, Vol. 2, No. 4, p. 4.

[9] "Hazardous materials regulations of the Department of Transportation" (1967) *Federal Register*, Vol. 32, No. 251, p. 20982.

low degree of toxicity and it would be difficult to envision any circumstances in which workers or bystanders could absorb sufficiently large quantities to produce poisoning. However, other pesticides, particularly certain organophosphate compounds, are extremely toxic and even very small quantities which could easily be absorbed by transportation workers, police, clean-up crews or even bystanders have produced poisoning. Knowledgeable evaluation of the toxic potential of the pesticide involved in a spillage accident is important to prevent possible poisoning from the more toxic materials and to minimize unnecessary precautions and concern if the chemicals involved are of low toxicity.

For this reason, spillage clean-up and safe disposal of toxic materials require personnel who have special knowledge of pesticides and chemical safety and who have proper equipment and sources of technical information available when an emergency arises. When a contamination incident occurs, it is possible that personnel from the pesticide manufacturing plant who have specialized knowledge of the toxicity and safety aspects of the specific chemicals involved may be called for assistance. In the United States, some major pesticide companies can provide a clean-up and decontamination team in certain areas; this service has proved to be very helpful.

Spillage incidents should be reported to proper authorities, especially local health officials. There may be situations where officials will find it necessary to take action to prevent movement of a contaminated vehicle or cargo until it is properly investigated or decontaminated. If cargo other than pesticides has been removed from a vehicle in which spillage of pesticides has occurred, the items should be located and checked for contamination. Careful consideration should be given to whether items intended for human or animal consumption should be destroyed, especially if they are in containers that can be permeated by the pesticide. It is necessary to trace the location of cargo that has been reshipped following a spillage incident in order to prevent any hazard to the receiver.

When pesticide spillage occurs, the hazard of the incident should be assessed and precautions immediately taken to prevent additional contamination. The contaminated clothing of an individual that has been exposed to toxic material should be removed as soon as possible and contaminated skin areas thoroughly cleaned with generous amounts of soap and water to reduce dermal absorption. Exposed persons should be placed under medical observation to ensure that any poisoning symptoms will be noted as early as possible so that prompt and proper treatment can be administered. This is especially important where contact has been with one of the more highly toxic organophosphate pesticides.

Waste pesticides, damaged containers and contaminated items should be buried in a location carefully selected to avoid contaminating surface or subsurface water (see chapter 8). If personnel from the pesticide plant are sent to the spillage site as a clean-up crew, they should be instructed to wear proper protective clothing and equipment. Use of cartridge-type respirators and water-repellent clothing, including rubber gloves and boots, are the minimum requirements for the clean-up crew of toxic pesticides. Pesticide contamination through spillage can present a serious clean-up problem. It may be difficult and perhaps almost impossible to decontaminate certain surfaces to the extent that all of the toxic

pesticide is removed. For example, if liquid concentrate parathion has been allowed to remain on wood flooring for any appreciable length of time, it is practically impossible to accomplish an adequate decontamination. The solvent used in the formulation apparently helps carry the toxic material into the wood and between the flooring strips to the extent that, in most cases, the only reasonable safety measure would be the removal and replacement of the contaminated wood.

It has been the author's impression from conversations with warehousemen and drivers and from personal experience with spillage incidents that there is a tendency to try to "clean-up" any spillage without contacting the shipper or pesticide company or obtaining other expert advice. The result is inefficient decontamination; lorries or trailers are dispatched on the next assignment, and the spillage area might lose its identity as a potential hazard. Therefore, it is important that personnel involved in transportation and storage of these materials know the proper precautions in handling and shipping toxic chemicals.

When pesticide has been spilled on flooring, the first inclination may be to "hose down" the floor with water to wash away as much of the pesticide as possible. This is not a good practice because flushing with water often spreads contamination over a wider area and causes the seepage of toxic material through the floor. In attempting to remove pesticide from a surface the first step should be to carefully remove as much of the pesticide as possible without enlarging the contaminated area. For dusts or wettable powders, the first step might be as simple as sweeping up the bulk of the material and disposing of it. The broom and other items used in this clean-up operation should be destroyed to prevent future use.

Large quantities of dust or wettable powders should never be picked up with a conventional-type vacuum cleaner with exposed collection bag. The fine inert material may penetrate the collection bag and engulf the operator in a cloud of toxic dust. Commercial vacuum cleaners designed for use in pesticide manufacturing plants are better suited for picking up dry pesticide. They are usually designed so that there is a minimum of leakage into the air during operation. After the first collection of loose material, these vacuum cleaners do a reasonably good job of recovering dry particulate material from seams and cracks in the surface, but it should not be assumed that adequate decontamination has been accomplished without considerable additional cleaning.

The first pick-up of liquid spills should be made by use of an absorbent material such as attaclay, fine sawdust, soda ash or even dry soil. Final decontamination should be with a chemical that is capable of degrading the pesticide. It is in this area of chemical decontamination that added research is needed because some of the materials that have been used for this purpose are not particularly efficient in degrading all pesticides. Some of the more readily available materials that have been used are sodium bicarbonate, household chlorine bleach (sodium hypochlorite), lye (sodium hydroxide) and hydrated lime as well as water and detergent. Furthermore, ethyl alcohol, isopropyl alcohol and trisodium phosphate have been used to clean surfaces.

Decontamination of metal lorry beds is possible if the flooring is continuous without seams or many bolt heads. Most metal lorry floors, however, have seams

and are badly gouged and scratched, therefore decontamintaion is very difficult.

A highway accident involving pesticides can present a serious hazard not only to those persons directly involved in the accident but also to those assisting the injured and to workers who clean up the wreckage and highway surface. In such a situation it is well to remember that any persons injured in a wreck should be checked to determine if their skin has become contaminated with pesticide. The removal of highly toxic organophosphate pesticide from the skin may be just as important and urgent as other first-aid measures for an injury. Almost any available liquid may be useful in cleansing contaminated skin in such an emergency. Travellers in waiting automobiles at the wreckage site may have liquids such as water, coffee, soft drinks or a bottle of baby's milk. People travelling in campers or trailers may be able to provide the more suitable pan, soap, water and towel or washcloth needed for a thorough cleaning job. If injured persons have been taken to a hospital without being checked for skin contamination, the hospital should immediately be advised of the possible hazard.

Employees of a pesticide manufacturing plant, who may be called to the scene of such an accident as experts on toxic chemicals, may not only be faced with providing life-saving advice as mentioned above but may encounter other problems associated with such an incident. In order to assess the hazard of the situation it is important to first determine the pesticides involved. If the shipping papers are not available or if they show that several different pesticides are in the shipment, it may be necessary to enter the wrecked vehicle to identify the compounds that are leaking onto the highway surface. At this time the foresight of having protective equipment available for such an emergency will be appreciated. The wearing of waterproof protective clothing and a cartridge-type respirator are the minimum requirements to enter wreckage contaminated with toxic materials. Where highly volatile toxic materials are involved, the use of a self-contained air-supply respirator system is advised. A battery-operated light for checking pesticide container labels in the dark and a shovel for covering spillage with soil are useful items.

The police should not allow unauthorized persons near the contaminated area. Footprints or tyre tracks across an area contaminated with a highly toxic compound should be cause for concern. In such a case, a check should be made to determine if anyone at the site is wearing contaminated shoes. Vehicles with contaminated tyres may be difficult to trace. One method that has been employed in the United States is by radio announcement. Toxic material on a vehicle tyre may present a hazard to mechanics, service-station attendants or small children who may play around parked vehicles.

If the pesticide spilled on the highway surface is a dust or wettable powder formulation, such dry material might be drawn into the ventilation system of a passing vehicle and create a potential hazard to vehicle occupants, especially infants. During windy weather, dry pesticide material can be blown some distance and may cause contamination of nearby areas. Covering dry pesticide with a tarp or moist soil may prevent some movement by the wind; however, strong winds

make this procedure ineffective. If a local fire department has equipment at the site, it may be advisable to "wet-down" the material so that it will not be carried by the wind or to flush it from the highway surface. However, this should be done only after careful consideration of the possibility of contaminating nearby streams or bodies of water. If the potential for contamination of such water appears to be greater through movement by wind than by flushing with water, the flushing may be justified. Washing of the roadbed or highway surface, however, spreads contamination and makes final clean-up more difficult. A fire department should not be allowed to flush pesticide down a street storm drain or sewage inlet.

The police may be anxious to learn whether it is safe to allow vehicles to pass a contaminated wreckage site. If there is any doubt about the situation, it would be wise to prevent traffic movement. If there is ample room for vehicles to pass a contaminated area and the compounds involved are relatively non-toxic, there may be some justification for allowing movement of traffic. In this decision, however, a thorough knowledge of pesticide toxicity is important.

Safe removal of the contaminated wreckage and clean-up at the site requires careful management of the activities. If a pesticide company sends lorries and crews to collect undamaged cargo or to dispose of waste pesticides and damaged containers, the workers should wear protective gear and take proper safety precautions. Undamaged cargo should be inspected to determine if it is contaminated. Care must be taken to avoid contaminating additional lorries, or towing equipment that are sent to the scene. As much cleaning of the wreckage as possible should be carried out before it is moved; otherwise there may be further spillage or drainage as the wreck is lifted or towed. A thorough cleaning with absorbent material should be accomplished before any washing with water. Contaminated wreckage should not be moved to any location where it might be a hazard. Thorough additional cleaning should be carried out in a safe location under the supervision of a responsible person. This is especially important if the damaged vehicle will be repaired by mechanics.

In cleaning pesticides from highway or road surfaces, it is advisable to follow somewhat the same procedure as noted above for other surfaces. The procedure should end with a thorough cleaning with water, although run-off into water supplies must be avoided. Contaminated soil, crushed rock or gravel areas should be dug up, and the waste material buried in a safe location.

The site should be visited the following day. By this time the road surface may be dried out, and it is much easier to identify any remaining contaminated areas. After final clean-up, samples should be taken at various locations for analysis as a check for effectiveness of clean-up procedures if a pesticide analytical service is available.

One of the problems related to pesticide storage and transportation is hazard from fire. Fire has been caused by spontaneous combustion of pesticides, and solvents in liquid formulations have contributed highly inflammable fuel to fires. Firemen, police and onlookers at a fire may be subjected to toxic pesticide fumes. During pesticide warehouse fires, there is undoubtedly much incomplete combustion, especially of wettable powder formulations. Thus, the toxic pesticide

compound as well as the break-down products may be present in smoke. Up to 7.9 mg of parathion/m^3 of air has been found in the smoke of burning wettable powder parathion from "empty" paper bags containing residues of the pesticide.[10] Although persons near a pesticide fire would not ordinarily be subjected to the fumes for any long period of time, the high concentration from burning bags containing only small amounts of parathion indicates that it may be hazardous to breathe the fumes for even a relatively short time.

Fires in pesticide warehouses and formulation plants have resulted in large quantities of pesticide waste which must be hauled and buried at a safe location. Where stacks of dry pesticide are involved, much of the materials may be only partly burned and, in the centre of tightly packed stacks, some of it may not be even charred. Clean-up crews should be warned of the potential hazard and instructed to wear protective gear when handling such material.

Summary

Wherever pesticides are stored or transported there is a potential hazard because of the possibility of spillage or fire involving material highly toxic to humans. Proper clean-up and disposal of spilled or waste toxic materials require the careful attention of personnel who have a thorough knowledge of such compounds. Personnel from a pesticide manufacturing plant may be called for expert advice and assistance in clean-up procedures. When pesticide spillages or fires do occur, the safety of personnel is of greatest importance. Despite efforts to prevent such hazardous situations, the number of incidents occurring each year indicates that continued vigilance in the field of transportation and storage is necessary in order to prevent pesticide poisonings.

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[10] Wolfe, H. R., W. F. Durham, K. C. Walker and J. F. Armstrong (1961) *Archives of Environmental Health*, Vol. 3, p. 531.

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PEST MANAGEMENT WITH INSECT SEX ATTRACTANTS
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EPA's Registration Requirements For Insect Behavior Controlling Chemicals—Philosophy and Mandates

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For those of you who do not know, I regretfully report that Dr. Len Axelrod suffered a fatal heart attack a few weeks ago, and needless to say, I feel very humble standing here in his place.

During the few years in which I had the distinct pleasure of associating with Len, he always received my deepest respect, not only as a scientist, but as a humanitarian who was greatly concerned with the welfare and survival of man and his environment.

So, without any further adieu, I would like to dedicate this presentation to Dr. Leonard R. Axelrod.

During the past year, Criteria and Evaluation Division has worked closely on a contract with the Zoecon Corporation. The purpose of this contract was to provide scientific and technical data to enable the Environmental Protection Agency to develop guidelines for the registration of pheromones and insect growth regulators. Part of what I am about to present is from the Zoecon Contract, as we take our first major step in developing the necessary guidance and criteria for the development and registration of chemicals for insect behavior control.

Since we are just beginning to develop these guidelines, I am not going to discuss the specifics on what needs to be done for evaluating efficacy, environmental chemistry, safety, etc. However, I will attempt to address the past, present, and future in our association with these materials for use not only as alternatives for some of the more highly persistent traditional pesticides, but also as an aid in reducing the chemical load entering the environment.

Historical Background

Although European naturalists as early as the 17th Century utilized caged virgin female moths to lure males for their collections, the field of chemical communication did not acquire appreciable sophistication until quite recently. In 1959,

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Karlson and Luscher coined the term "Pheromone" to refer to substances which are emitted to the outside by an individual and received by a second individual of the same species which responds in a specific manner, such as a behavioral response. (The singular term "Pheromone" refers to one or several chemical compounds eliciting the response). Two years later, the German chemist Butenandt and co-workers culminated a 20-year effort by identifying the male sex attractant from 500,000 silkworm moth females, the first such natural chemical message system to be decoded. These two events plus an increased interest in alternate pest control methods have helped stimulate numerous research programs directed toward the understanding of the biological function of the chemical structure of pheromones.

For the purposes of the EPA Guidelines for Registration, the term "Pheromones" will also include non-pheromone chemicals, which elicit or modify behavioral responses. Included in this category will be attractants discovered by empirical screening.

A Sampler of Behavioral Functions

To date pheromones have been found to mediate a diverse repertoire of behavior patterns ranging from those in unicellular organisms to those in the primates. As a partial sampler, insect pheromones have been found to regulate such phenomena as aggregation responses, including trail following as in ants and termites, host colonization as in attraction or mass attack of bark beetles to trees, and recruitment ("Calling") of sexual partner as in attraction of males to female moths. In other chemical stimuli systems, dispersion away form the released pheromone occurs. This occurs in the case of an alarm substance emitted from an attacked aphid which causes the aphid's neighbors to escape predation by rapidly dropping from the plant. Alarm pheromones can also serve to mark an enemy for attack by additional individuals, a phenomenon many of us have encountered after being stung by a social hymenopteran such as a bee or a wasp. Other patterns of pheromone response include colonial behavior in many social *Hymenoptera* (such as bees and ants) and the *Isoptera* (termites). Generally, the queen emits the "master" pheromone which serves many functions including colony membership identification and eliciting the retinue behavior of feeding and grooming the queen. Examples of some of the chemicals that mediate behavior are listed in Table I. More extensive information can be found in recent reviews by Jacobson and Shorey.

The sensitivity of the messenger reception system to the pheromone is of an extraordinary nature. In the male silkworm moth, a single pheromone molecule can elicit firing of an olfactory neuron on the male antenna, whereas some 200 molecules are required for an overt behavioral response as male movement toward the odor source.

Table I: Examples of Chemicals Mediating Various Behavioral Responses in Insects*

Scientific Name	Common Name	Chemical Name	Response
Limonius californicus	Sugar Beet Wireworm Beetle	Valeric Acid	Male Attraction
Porthetria dispar	Gypsy Moth	cis-7,8-Epoxy-2-Methyloctadecane	Male Attraction
Trichoplusia ni	Cabbage Looper Moth	(Z)-7-Dodecen-1-ol Acetate	Male Attraction
Anthonomus grandis	Boll Weevil	1) (+)cis-2-Isopropenyl-1-Methylcyclobutanethanol	Female & Male
		2) (Z)-3,3-Dimethylcyclohexylideneethanol	Attraction
		3) (Z)-3,3-Dimethylcyclohexylideneacetaldehyde	(Aggregation)
		4) (E)-3,3-Dimethylcylohexylideneaceta:dehyde	
Apis mellifera	Honeybee	1) 2-Heptanone	Alarm
		2) Isopentyl Acetate	
Zootermopsis nevadensis	Termite	Hexanoic Acid	Trail-marking

*References can be located in Jacobson, M., In Rc[illegible]ein, The Physiology of Insecta, 2nd ED., 3:229-276. 1974 (Academic Press, New York)

Elucidation of the chemical structures of pheromones has lagged behind the description of the general behavioral functions. Generally, evidence of the presence of a pheromone by observation of the specific behavior must precede bioassay and isolation. In 1966, several insect pheromones were chemically identified, and since then the number of compounds characterized has increased steadily, due in part to the increased sophistication of the instrumentation for chemical analysis. As the synthetic pheromones have become available, biologists have been able to decipher their exact behavioral function and applied entomologists and zoologists have been able to initiate programs designed to utilize pheromones for pest population manipulation.

Principles

Generally, the development of pheromones into a chemical system for pest population manipulation, such as mass trapping or disruption of pheromone communication, initally involves chemical characterization of the pheromone system, chemical synthesis, and laboratory and field documentation of the behavioral responses elicited by the pheromone. Once the structure and evoked biological response are described, evidence of the effectiveness and usefulness of the pheromone for population manipulation must be established through field testing under natural conditions.

Use of Pheromones in Pest Monitoring

The most immediate and obvious use of synthesized pheromones has been for population monitoring, essentially an extension of the early naturalists' use of female moths to lure males. A synthetic pheromone in a sticky trap, for example, lures and ensnares the pests. The numbers caught can be used to estimate the pest's relative abundance and seasonal development. This information may permit decisions to be made as to the exact timing of insecticide applications for maximum effectiveness or even a determination of the necessity for a conventional pesticide application. For certain crops, this precise population sampling technique may allow substantial reductions in the standard pesticide application, with the use of only 0.015 to 0.00003 gram of synthetic pheromone per acre in a single trap.

A typical case of such a benefit occurs with the monitoring of the summer fruit tortrix moth in the Netherlands. The maximum benefit for an insecticide spray with this species is derived when the application occurs a few days after egg hatch, just as the larvae are migrating to their feeding sites. This susceptibility window can be predicted accurately through the use of pheromone traps, and their widespread use in the Netherlands has resulted in the use of fewer insecticide applications with more effective control.

Similar monitoring programs for a number of pests such as the codling moth, the peach twig borer, and the oriental fruit moth are in the research and development stage. Population monitoring with commercially available pheromone traps has been adopted by some commercial growers as part of integrated pest management programs. Monitoring systems are not regulated by the EPA since this pheromone use is neither designed nor claimed to suppress population levels.

Mass Trapping for Population Suppression and Control

Several distinct methodologies for pheromone utilization in direct population manipulation have been described. The technique of mass trapping utilizes compounds which lure one or both sexes to a mating and/or aggregation locus. In mass trapping these compounds are emitted from a dispenser and the attracted pest becomes ensnared in a sticky trap or a device of similar principle. Success of this method depends upon removal of a sufficient portion of the pest population so as to reduce damage or nuisance to an economically or medically acceptable level.

Efficacy in mass trapping involves not just the description of the actual number of pests captured in a test, but, additionally, it requires some independent estimate of the effect on the total pest population and/or of the damage reduction.

In some successful mass trapping experiments, the quantity of pheromone used per acre was less than 0.04 grams (0.00009 lbs) or roughly 1/10,000 the quantity per acre for several conventional pesticides. In the case of other pest species, the total amount of pheromone per acre could be substantially less than this amount.

In mass trapping an attractant-baited trap generally serves to capture the pest. Traps are set out at a density which is sufficient enough to remove the proportion of the breeding pest population necessary for population suppression.

For example, in the case of the redbanded leafroller moth, a species in which the female-produced pheromone lures the male for mating, 40 attractant traps per acre in an apple orchard will remove enough males to effect control of this pest, providing that this technique is used on low initial populations. For this species, a low population could be achieved by application of a conventional insecticide prior to the initiation of the pheromone program. A low population also would exist in a well-managed commercial apple orchard.

A mass trapping population manipulation technique would possess the following advantages over conventional pesticides:

1. Highly specific control of the target organism;
2. Facilitation of biological control of non-target pests;
3. Use of a compound which is designed to attract rather than kill at rates comparable to natural pheromone levels.

Population Suppression by Disruption of Communication

Another promising means of using pheromones or attractants in an integrated pest management program is through disruption of pheromone communication, a procedure first demonstrated by Gaston and co-workers. Population manipulation involving disruption of communication is dependent upon atmospheric permeation with a sufficient concentration of communication component chemicals to prevent or greatly alter the pest's olfactory perception and orientation toward the natural pheromone sources.

Research experiments with many moth species have demonstrated that emission of these communication disruptants into the air prevents the male's successful location of the female, thereby effecting a reduction or elimination of mating. The disruptant employed could be the natural pheromone chemicals reconstituted in a different proportion or rate, or a compound which by itself is not part of the natural communication system but which affects the behavioral response. Successful communication disruption thus generally prevents crop damage in the following generation by reduction or elimination of mating in the present generation. Efficacy evaluation again requires precise sampling of total pest populations and accurate estimates of crop damage.

One technique for dispersal of the pheromone into the atmosphere is emanation of the compound from point source dispensers. Such evaporating devices can be deployed at a set number per unit area and are recoverable (i.e., can be removed after use), so that the pheromone is dispersed only into the atmosphere and not sprayed directly onto the foliage, crops, soil and target or non-target organisms.

Another method of pheromone application is similar to that used for conventional pesticides. In this procedure, a pheromone formulation (involving microencapsulation, wettable powders, or other volatile release matrices) is sprayed with standard pesticide equipment.

Experiments conducted to date indicate that rates of only 10 grams (0.02 lbs) or less of pheromone per acre per application may be more than adequate for communication disruption for several weeks. The specific test protocol necessary to demonstrate efficacy will be dependent on the characteristics of the pheromone compound, the nature of the manipulation technique chosen, the nature of the crop, the timing of the application, and the biology of the organism.

Current EPA Philosphy

The public's concern for the environment is one of the factors motivating the development of new agents for insect population control. At the present time, most research, notably in industry is still concentrated on hard chemical insecticides,

especially directed toward modifications of existing structural types such as organophosphates, organotins and carbamates. The emphasis is on agents with less persistence, improved efficacy, and greater specificity to target organisms.

Insect pheromones in general are highly selective; each pheromone is limited to a particular insect, or at most, to several related species. The most efficient pheromones appear to be chemicals which are produced by the insects themselves, or by host plants. They are effective in extremely small quantities. They are attractive to a particular stage of the pest insect, generally the adult stage, and they are used only during a limited time of the year. By their very nature, natural pheromones have been presumed to be relatively non-toxic to man and other non-target organisms. However, extensive investigations concerning the possible hazards or adverse effects of pheromones to man and the environment are necessary to determine the safety of their use as pesticides, especially when synthesized.

Although pheromones exhibit highly desirable characteristics as insect control agents, commercial interest in chemicals which are effective against a single species on a sporadic need basis is generally limited. Understandably, the chemical industry does not wish to bear the high cost of research and development for materials with limited profit, however, the USDA is carrying out the development of pheromones as part of their thrust toward integrated pest management systems.

At the present time pheromones are mainly used as survey tools for monitoring populations and many investigators feel that this use of pheromones will be the key to integrated pest control programs for many crops. Pheromone baited traps for monitoring purposes have the following specific uses:

1. To determine proper timing of sprays;
2. To locate sources of infestation from over-wintering areas;
3. To detect a new pest coming into a region;
4. To determine if a pesticide spray is actually needed.

In the future, pheromones may be used for control of certain insects. Current thinking is that control with pheromones may be effective in two ways.

1. By mass trapping of one or both sexes;
2. By confusion of the insects through communication disruption, i.e., the insects become confused and die before mating occurs.

Certain of the compounds are included in major programs being carried out as part of the thrust toward integrated pest management, in particular, gossyplure for pink bollworm, grandlure for boll weevil and disparlure for gypsy moth.

Pheromones for numerous insects are available for experimental purposes and a small number are available for commercial uses. Because of the long experience of industry and government with chemical pesticides, the registration requirements and

development procedures are best defined for the "traditional" chemical control agents. Safety, efficacy and environmental requirements which have evolved for traditional insecticides are the standards by which practically every new chemical control agent is evaluated by the EPA. The cost of developing any new and novel method of insect control, falling within the jurisdiction of the EPA, is going to be at least as expensive as the cost of developing a traditional chemical insecticide. In addition to the baseline requirements established for the traditional insecticides, new agents (even in the "experimental permits" and "temporary tolerance" phases), may be required to undergo additional studies some of which may be new and unique.

Proposed Regulations and Recommendations

Safety-Hazard Evaluation. Hazard evaluation requirements should strongly consider the use pattern and the basic safety of the individual materials. The requirements may be entirely different if the pheromone is applied by point-source release versus being broadcast over an area in the form of a spray or granular formulation. Also, with a pheromone, one must consider whether or not the compound occurs in nature, and possibly in what concentrations. A further distinction in the requirements might also be made between a point-source release mechanism which is not recoverable versus a point-source release mechanism which is recoverable.

Efficacy - Use Pattern Criteria - Labeling. With pheromones it is felt that some term should be used other than "control". There is a wide variation of terms that could be used, but, generally, it is felt that terms such as "population suppression" or "aids in control" are more suitable particularly where the usefulness and efficacy of the product are based on its ability to protect foliage and/or on its ability to prevent mating, thus leading to possible population reduction in a manner other than by direct kill as experienced with traditional hard chemicals. Perhaps the most controversial area in obtaining pheromone registration revolves aroung the fact that even though there may be a reduction in mating this does not necessarily mean there is a reduction in the population of a species. This is why the term "aids in control" may be more appropriate for pheromones which are employed as an integral part of an integrated pest management system. In addition, resistance to pheromones, especially those used for monitoring, should not develop, thus insuring a longer market life for pheromones.

Catches in pheromone baited or organism-baited traps or mating incidence in the treated areas are supportive of efficacy but such data do not constitute a demonstration of efficacy.

Field Plot Techniques. Field plot techniques acceptable for traditional pest control in general are acceptable for pheromones but may vary depending upon the biology of the insect and

adaptability of the product to certain pest management practices. Each individual pheromone development must be considered on a case-by-case basis, and criteria such as plot size, number of replicates, geographical test locations, etc., should, out of necessity, be subject to revision depending upon the problem at hand.

Areas which may have to be investigated in addition to what is presently done with traditional pesticides are as follows:

(A) Necessity for obtaining more details on the biology of the insect, the stage of development present at time of application and the percentage of the population in each stage.
(B) The necessity for compiling past history records on insect populations, on the treated area and in adjacent areas.
(C) The necessity for compiling records on adjacent crops and areas, for the season of the experiment and, possibly, for the seasons before and after treatment.

Current Registration Status

When used as survey tools in integrated pest management programs, the pheromones are not subject to the Federal Insecticide, Fungicide and Rodenticide Act, unless used in conjunction with a pesticide which is subject to the Act. If used as an attractant in a control procedure or in insect mitigation, pheromones are subject to regulation under the Act.

The pheromone field as a part of the science of entomology has advanced rapidly in the past decade, and in particular, in the past few years. At present, muscalure is registered as an attractant in fly baits. This pheromone is specific to houseflies, for which the baits are so intended; however, other species of flies may be attracted by other ingredients in the bait. The rationale for registering muscalure differed from other basic attractants in that its action as a sex attractant incorporated in the bait, permitted a reduction in the concentration of a more toxic chemical pesticide and increased the efficacy of the product. This constituted the first registration of a pheromone for insect control.

Extensive field experiments have been conducted by the USDA to assess the potential of disparlure in controlling the gypsy moth by communication disruption techniques. Due to the method used and type of results obtained, it will be necessary to employ criteria for reg stration based on foliage protection and/or inability of the insect to mate and propagate the species, rather than on the basis of population reduction obtained through direct kill. Disparlure is in the advanced stages of development under an experimental permit, and registration appears possible within a year or two.

Experimental permits have also been issued by EPA for codlemone, a sex attractant for codling moth, and grandlure, the

boll weevil aggregation pheromone, which is currently in for registration.

Current Progress

Scientists in the Registration and Criteria and Evaluation Divisions have begun a joint effort to develop guidance and criteria for the efficacy and safety evaluation of pheromones. The purpose of this guidance will be to assist registrants with the registration requirements for developing and testing these compounds, and to assist the review process with the evaluation of such products when submitted for registration.

The "Guidance and Criteria" package will be developed in a separate document paralleling the general registration guidelines in format, but applicable specifically to the development and testing of these type compounds.

This will further enable us to circulate and work on this document with the Registration Division until the requirements and methods are suitable to both Criteria and Evaluation Division and the registration process, thereby preventing the problem of constantly modifying the general registration guidelines. The anticipated completion date for the pheromone guidance and criteria will be the end of the current calendar year, as we move forward in the area of new pesticide products.